

Proprietary. v2.0 \*

## Advanced Continental Low-VHF 20-55 MHz Meteor Burst Radio Signaling Networks

(MB) (MBRS)  
and

## Low VHF Ground Wave Radio Signaling Networks (lvGWRS)

**EXHIBIT 1, part 1  
to SSF 3-14-16 Filing in  
FCC docket 15-282**

For critical infrastructure & services, including:

**MBRS:** for broadcast data (for N-RTK for GPS/ GNSS high accuracy; other), 2-way comms, MB positioning navigation & timing (GPS independent) (“iPNT”), MB encryption, atmospheric science and prediction...

**GWRS:** for best, low interference and attenuation, LOS & NLOS networks in urban and indoor iPNT and low-rate networks for geolocation, ground drones, search & rescue, smart cities and buildings...

### Before the NTIA and US PNT Agencies

By Warren Havens, Berkeley CA. January 2016. \* Copy and related at: [polarispnt.space](http://polarispnt.space)

Federal and other government entities hold substantial radio spectrum in the ranges suitable for MBRS. Advanced MBRS, as indicated herein, can provide highly cost effective and critical benefits to the nation.

Wireless **pPNT** – radio *signaling and data* for **precise position, navigation and timing**— is far more important than wireless *communications*. Advanced MBRS & ivGWRS can and should play a major role in nationwide pPNT.

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\* Upon federal entity request, I may provide a confidential, expanded version of this presentation that expands material herein with information and ideas that are my trade secrets subject to patent actions.

## Advanced Meteor Burst Radio Signaling

Billions of small meteoroids enter the atmosphere daily, few large enough to be visible, and create no-cost, ever-renewed, smart, plasma antenna arrays in the sky, responsive to 25-55 MHz.

With new radio, antenna and computer techniques, this will enable '4G' and '5G' Meteor Burst Radio Signaling services that are robust, secure, continent wide with no coverage gaps, at low-cost-of-coverage.

It will deliver n-RTK for precision GPS nationwide. It will also provide Position, Navigation and Timing services independent of GPS and far more secure from sky or terrestrial attacks. It will also improve atmospheric and weather science that is much needed, and provide other major benefits.

NTIA and FCC spectrum is available, and otherwise is little used.

Reception of the many key data services will be via one-way broadcast, receivable in any radio device, even consumer smart phones.



<http://www.oceanlight.com/log/category/new-work> | [light@yosemite.earth](mailto:light@yosemite.earth)

This is a slide below, also included here at the start to show that Meteor Burst Radio Signaling is well established as to *basic principles and technology*.



The National Water and Climate Center (NWCC) has developed efficient and highly effective technology to provide the data needed for water supply, climate, analysis, and conservation planning. NWCC acquires additional data sets that are needed from other networks and designs local data networks and sophisticated national networks. NWCC operates a variety of networks that use different data acquisition technology. We offer our expertise to others through documentation, training, partnership, on-site assistance, and participation in professional forums. Briefly, some of the types of data acquisition technology that are currently established are:

NRCS SNOTEL shows MBRS is successful for NCRS's critical purpose. Advanced MBRS discussed herein may, under on plan, complement SNOTEL in a 'partnership' – see left.

### Meteor Burst Communication Technology

Meteor burst communication was discovered by the military in the 1950's. NRCS implemented this technology and developed SNOTEL in 1975. Meteor burst communication uses the billions of sand sized particles (1 gram or larger) that burn up in the 50 to 80 mile high region of the atmosphere to relay radio signals back to the earth. This technique allows communication to take place between remote sites and a master station up to 1200 miles away. At the master station, the remote site data is checked for completeness. If so, an acknowledgment message, returning over the same path, tells the remote site not to transmit again during this polling period. The entire process takes place in less than a tenth of a second. Meteor burst communication has proven to be extremely reliable. From the master stations, the data are sent via telephone line to the NWCC Central Computer Facility.



### Electronics Maintenance Facility

The NWCC operates a SNOTEL electronics maintenance facility that maintains a fully functional complement of modular SNOTEL components that can be sent overnight, worldwide if a component fails. The facility also repairs data acquisition systems sent in from the field, designs custom interface boards, tests sensors, keeps abreast of latest technology, and provides answers to technical questions related to data acquisition technology.

<http://www.wcc.nrcs.usda.gov/publications/Briefing-Book/bb25.html>

## Low VHF Ground Wave Radio Signaling Networks

This is derived from slides below, included here as an introduction.

### Low VHF Channel Measurements and Simulations in Indoor and Outdoor Scenarios

by F T Dagefu, G Verma, C R Rao, P L Yu, J R Fink, B M Sadler, and K Sarabandi, Computational & Information Sciences Directorate, **ARL** | K Sarabandi Dept of Electrical Engineering and Computer Science, University of Michigan

The **lower VHF band** has potential for low power, short-range communications, as well as for **geolocation** applications, in both **indoor and urban** environment.... both line-of-sight (LOS) and **non-LOS (NLOS)** cases.... [T]he measured channels have a **nearly ideal scalar attenuation and delay transfer function, with minimal phase distortion**. Compared with higher VHF and above, the measured short-range VHF channels do not exhibit small-scale fading, which simplifies communications receiver signal processing, and **enables phase and amplitude based geolocation** techniques.

The lower VHF band... scatterers are small in terms of wavelength.[ ] Consequently, **strong penetration through multiple walls and buildings** can be achieved at relatively low power. **Reflection, scattering, and diffraction phenomena are dramatically reduced**, thereby **greatly minimizing multipath fading**, yielding a **short-range channel that is LOSlike** in terms of very slight phase distortion and delay spread. This liberates the system designer at low VHF from the typically stringent requirements on power, system bandwidth, and complex equalization processing needed in ultra-high frequency (UHF) and microwave based systems....[D]ue to **recent advances in antenna miniaturization** techniques and the development of **palm-sized lower VHF antennas with good performance**,[ ] interest in low power, low data rate communications in this band is increasing.... [I]n North America, there is a dual

allocation at low VHF..... [T]he primary allocation **near 38 and 40 MHz** is for Federal use.... The simplicity of the channel, along with recent advances in the design of extremely miniaturized lower VHF antennas, can be exploited in a large variety of signal processing and communications applications **including geolocation in GPS-denied environments** and... in search-and-rescue operations.

Published online by ARL. Also in: IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, VOL. 63, NO. 6, JUNE 2015



**US Army Research Laboratory**



Fig. 8 ... view of the test facility. **P0** and **P1** are the 2 transmitter positions and **R0 to R9** are various indoor and outdoor regions traversed by the robot for data collection



**Small Antennas for Low VHF Comms**

## Section Contents & Narrative

- I. Advanced MBRS – what and why
- II. Advanced MBRS – how – technologies

### I. Advanced MBRS – what and why

1. Introduction, need and goals
2. Presentation context
  - FCC and US have authority...
3. US PNT Agencies
4. What is MBRS, and Advanced MBRS
  - US PNT (Position, Navigation & Timing) and Federal Radionavigation Plan
  - US DOA NCRS example - SNOTEL - 700+ stations for environment monitoring
  - Advanced MBRS and GPS are related
  - DOA, NOAA, US GPS office (at DOC) should cooperate on MBRS including for ipPNT (GPS- independent precise Position, Navigation & Timing)
5. Why MBRS is unique and critical including for national security and productivity, by providing (see also 13 below)
  - (i) GPS-independent pPNT (precise Position, Navigation & Timing) underlying smart infrastructure and services
  - (ii) ubiquitous wireless far more robust and survivable than any terrestrial, satellite or landline wireless
  - (iii) the base-communication-foundation for smart infrastructure, services, and environment monitoring and protection
6. US always has been and - *may* - remain leader in MBRS and GNSS
  - This should be advanced, but if not pursued now seriously, Russia, China and others are advancing MBRS
7. Deployment of MBRS
  - (a) NTIA-DOA-NOAA lead and preemption, (b) FCC cooperation, and (c) nonprofit “private commons”
  - Federal and cooperative State and local government have dedicated MBRS (VPN and otherwise), and others have private commons (as FCC defines) access to create large demand and development (similar to DARPA model)

In this v 1.0, some sections below combine a number of related outlined in this Contents list. The list provided a useful outline of topics covered in slides below.

See also -

[POLARISPNT.SPACE](#)

See footnote on the cover slide above, regarding confidential additions.

## Section Contents (continued)

8. [Spectrum availability](#) (and no other spectrum users affected)
  - NTIA spectrum, FCC licensed spectrum, TV low-band 'white space' spectrum, and other for passive MBRS radar
  - Smart and cognitive basis - especially suitable in MBRS
9. [Low VHF Noise reduction, and noise benefits](#)
  - And why ~40 MHz (25-55 MHz) should primarily be for MBRS, augmented by terrestrial wireless in same and other ranges
10. [Practical time now for Advanced MBRS](#)
  - Convergence of needs, with advances in computer, radio, antenna, and other tech, and projections
11. [Why ipPNT \(GPS-independent precise Position, Navigation & Timing\) is more important than radio communications](#)
  - "Smart," secure, stable systems are based on precision of time and location (how the Universe works)
  - GPS and GNSS is not and cannot be sufficiently secure from space and terrestrial attacks – and needs a backup
  - MBRS ipPNT can be coordinated with NIST timing services, and any other GPS augmentation and backup
12. [MBRS and nationwide drone wireless – mutually beneficial](#)
  - FAA application: MBRS delivery of nRTK to drones for precise movements, and height and 2d boundary policing.
  - MBRS can use drones with synchronized antennas for one- /and two- way MBRS signaling from/to master stations
13. [Easy implementation in all 'smart' phones and other radio devices- vendors pay nominal costs](#)
14. [Early phase commencement using existing federal and TV stations – nominal costs](#)
  - Second phase should and would not need them, but can continue to use for enhancement
15. [Substantially applicable cost benefit studies- University of California Berkeley and others](#)
16. [Integration of Advanced MBRS and lvGWRS for Ubiquitous Continental+ ipPNT.](#)
  - Same mobile transceivers, and the two solve urban and indoor RF NLOS inaccuracies and attenuation in higher bands

[Go to next page]

## Section Contents (continued)

II. Advanced MBRS – technologies

1. Advances in MBRS in recent periods (after preceding “traditional” MBRS).
2. Integration of MBRS in ‘smart’ phones and other radio devices.
3. MBRS for ipPNT – GPS independent precise Position Navigation and Timing.  
In most all federal agency goals.
4. MBRS for pPNT via nRTK (network real time kinematic GPS/ GNSS).  
In many all federal agency goals.
5. China and Russian MBRS work (mostly kept non public)
6. SDR remote transceivers to match the base arrays, and the ipPNT functions
7. Radio Astronomy and Earth Atmosphere (radar) base station arrays and computing
8. SDR tech and products for multiple purposes (base, remote, relay, and other radios)
9. Bi- and multi-static MBRS radar and related
10. Passive MBRS radar (part of ipPNT) using TV and federal station stations
11. MBRS for GPS- or-better timing (fully independent of GPS/ GNSS)
12. MBRS for encryption (of any signal)- benefits over math-based encryption. In all Federal agency goals.
13. MBRS for earth atmosphere and weather prediction, as as foundation for possibly needed mitigating changes in Ionosphere to counter global warming. In DOA and NOAA goals, and indirectly other federal agencies.
14. MBRS in support of super wide area radio astronomy (adjacent frequencies).  
In NSF National Radio Astronomy Observatory goals.
15. Low VHF Ground Wave Radio Signaling Networks (lvGWRS)  
In US Army goals. Extensible to all federal and other government agencies.

In this v 1.0, some sections below combine a number of related outlined in this Contents list. The list provided a useful outline of topics covered in slides below.

See also -

[POLARISPNT.SPACE](#)

See footnote on the cover slide above, regarding confidential additions.

## *Proprietary*

### Introduction

Warren Havens, the author of this presentation explains:

I prepared the website : [www.terranautox.com](http://www.terranautox.com). Hererin, I do *not* refer to any licensee or license in that website.

Herein, ~40 MHz” and “40 MHz” means 25-55 MHz +/-, the ideal range for MBRS.

The various aspects of MBRS, and most of the technologies herein, are not well known. Explanations of the fundamentals and details of each are in extensive public sources, many found by “googling.” While I provide substantial explanations below, mostly in Part I, a better understanding of this presentation requires additional background knowledge.

MBRS can be used directly for pPNT (independent of GPS/ GNSS), and indirectly by delivering nRTK data and in other ways.

Wireless pPNT – radio *signaling and data* for precise position, navigation and timing-- *is far more important* than more wireless *communications*. E.g., see [www.terranautox.com](http://www.terranautox.com). Also see [www.polarisPNT.space](http://www.polarisPNT.space).

For the needed ubiquitous nationwide pPNT, lowband VHF is needed. Nonprofit public- private commons are needed as well.

For more capacity in high-use areas, other spectrum and networks would be used and integrated.

The following slides primarily give information on current advanced technology available as-is, or with reasonable adaptation given the scale involved.

Comments below in boxes are added for further explanation of the text and graphics, most of which are largely self explanatory in context of the slides above, including the p. 3 chart, for the suitably informed reader.

Most of the below are excerpts from the documents named. Underlining is added. Online sources shown.

## I. Advanced Meteor Burst Radio Signaling (MBRS) – what and why

# 1

## Introduction, Need and Goals

## Goal, Need, and Plan - 1

Ubiquitous “3D Wireless” is needed, and [Advanced MBRS](#) should and can be its foundation

Currently, the vast majority of wireless is flat-earth bound and thus “2d,” and uses wave forms that are also 2d since OAM and similar 3d wave forms cannot work well in NLOS 2d that predominates, and lacks precision in time and space even in 2d (it is fuzzy). This “flat” and “fuzzy” wireless imposes severe limitations, as is imposed when someone cannot balance, see and hear well.[1]

The exceptions are satellite communications and lightly used low spectrum skywave communications [2] [3]. 2d flat-fuzzy wireless lacks the [height](#) dimension and with it, LOS propagation, and with that, huge gains in ERP effectiveness, signal-level predictability, vertical polarization, and accurate time transfer (GPS level or better) and thus the basis to securely [see 4] cure the fuzziness via pPNT.

[Advanced MBRS](#) will provide [3d wireless](#) nationwide, Continental, and Intercontinental (easily worldwide, when coordinated) in a highly cost effective and secure manner, and provide LOS-based functions including GPS- independent Position, Navigation and Timing (“ipPNT”) for a foundation of all “smart” critical infrastructure and services.

Based on Ionosphere heights, advanced MBRS will very cost effectively [cover everywhere](#), even in most remote areas and far offshore (by 1,000 miles or so, and more with relays on ships and islands). The more it is used at base and remote stations, the more capacity is generated. It can deliver nRTK corrections (already for the most part available in the US land mass, via NOAA CORS, etc.) on broadcast basis to everyone at not cost to recipient, and nominal total costs of delivery.

[Advanced MBRS](#) will provide [3d wireless](#) because it is based on Ionospheric radio wave propagation, and it will be highly cost effective, and spectrum efficient, due to using the “free” billions of “smart antennas” in the Ionosphere that appear daily by plasma trails created by grain-sized meteoroids that burn up in the Ionosphere creating this plasma trail antennas.[4]

Advanced MBRS 3d wireless will integrate easily with, and extend and protect, other wireless, in many ways, including but not limited to use of and by drones. Advanced MBRS adds other benefits shown below.

[1] Thus, e.g., movement to commercial ‘5G’ is highly difficult and costly. Government, even military government, wireless is further behind on its ‘5G’ including since the developments are so complex that it cannot keep up with the commercial sector.

[2] Troposcatter and HF primarily. But these have far more cost, antenna-size and other limitations vs. advanced MBRS.

[3] And certain military super low frequency, very low data rate signaling through the earth and seas: not considered here.

[4] No hostile party can knock these out or jam them, as is easy to do with GPS. MBRS is far more survivable even in a nuclear attack (surface, or high-altitude EMP to “fry” many electronics) or severe solar flare or coronal mass ejection that also may “fry” these. This is explained in various US government studies and private publications, found online.

## Goal, Need, and Plan - 2

**Goal & Need:** Nationwide (i) *RF private commons*, accessible by all, as the foundation of Precise Infrastructure, which is *precise Position, Navigation & Timing* (pPNT) that augments GPS-GNSS, but is independent, and has high security and robustness. (ii) *Secured federal-use capacity*.

**Functions:** pPNT-based: (1) GPS-GNSS alternative PNT, (2) natural-environment 'infrastructure' (terrestrial & atmosphere), (3) manmade infrastructure including ITS (intelligent transportation systems), (4) drones (air & ground), (5) improved Ionospheric science, & weather prediction, & engineering (if needed), (6) whitespace broadband, (7) emergency response, (8) encryption security, (9) 5G+ commercial wireless.

A - *Physical RF & Technical Needs*

Robust and nanosecond synchronized:

- ① Nationwide RF spectrum (**Spectrum**) for super range (**Range**) RF links (**Links**)
- ② Spectrum redundancy (**RF Redundancy**)
- ③ Link propagation redundancy (**Links Redundancy**)
- ④ BoC (best of class) data broadcast links over Range (**Broadcast**)
- ⑤ BoC 2-way links over Range (**2-Way**)
- ⑥ Chips for core functions (**Chips**)
- ⑦ Super-gain base antenna arrays (**Base Arrays**)
- ⑧ Improved remote radio antennas (**iAntennas**) including phased Mesh
- ⑨ Remote radios fixed and mobile mesh nets (**Mesh**)
- ⑩ High redundant encryption (**Encryption**)

B - *Problems to date* (industry- markets)  
(keyed to #'s under A)

1. **A.1.** No one has taken the time and effort but the this group.
2. **A. 1-10.** Takes too much long-term foresight, research, development. Does not fit in commercial or government business models of any other entity or coordinated group.
3. Others, except higher levels in the US PNT (GPS and related) community, have not understood *precise Position, Navigation & Timing* or pPNT and why it is the essential need for effective and secure Functions described above. As in quantum physics, space (location) –time (thus navigation) is the foundation or field of matter-energy-observers).

Pages below give details

C – *Polaris PNT Solution -*

1. **A. 1-3.** The A.1 the **Spectrum**: government has it. Private, including private nonprofit can partner.  
**Range**, and **RF Redundancy**, and **Link Redundancy** are by mid-VHF long range terrestrial Links, and 25-55 MHz Paging super long range terrestrial and skywave Meteor Burst (MB) RF Links.
2. **A. 4. Broadcast:** Digital Radio Modiale for terrestrial, and one-way next-gen MB for MB Links.
3. **A.5. 2-Way:** New-gen MB and terrestrial (below).
4. **A.6. Chips** available and cost effective (below).
5. **A.7. Base Arrays:** available, based on radio astronomy and earth-atmosphere wide-area distributed phased array advancements (essentially, computer tech applied to simple antenna elements for super-gain, long-range receive and radar).
6. **A. 8, 9.** Also available now – see below.
7. **A. 10.** Via MB nanosecond timing and MB plasma-trails' unpredictable-characteristics-based encryption.

\* '40' MHz\* means 25-55 MHz. / Terranautx is at [www.terranautx.com](http://www.terranautx.com) but we do not put some, confidential data there. / The "Private Commons" herein means what the FCC means by this.

### Certain Terms

- 200 MHz - means the ~ 130 - 235 MHz range
- 40 MHz - means the ~ 25 - 55 MHz range (herein, '40' MHz) [1]
- 900 MHz - means the ~ 700 - 1200 MHz range [2]

The same phased array,[3] chip, & other tech is at hand for all 3 ranges for the wireless systems for the Functions described on page 3 above (together, the "Systems"):

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### Notes

- [1] Private and federal spectrum surveys show that a lot of spectrum in this range under NTIA OSM rights, is not in use, and may be available in some may be available in public-private partnerships with federal agencies via NTIA OSM authorization, as we plan.
- [2] Among available bands is n-LMS, 14 MHz in bandwidth, for government ITS networks.
- [3] E.g., "LOFAR" which means the Low Frequency Array for radio astronomy and certain atmospheric and terrestrial science. "EISTAT" means the European Incoherent Scatter radar facilities, for atmosphere and ionosphere science and prediction, and other purposes. These and other similar facilities, some also noted below, including "KAIRA", use software defined radios and antennas that may be adapted for radio base-station transceivers for expanded purposes, as discussed herein. In abbreviated form, like technologies can be used in remote radio devices, some presented below.

- I. Advanced Meteor Burst Radio Signaling (MBRS) – what and why

## 2

# Presentation Context

## Context

Public records show a constrained context of this presentation. There are actions to remove the constraints which, in part involve the following principles of law.

The US Supreme Court stated in *WOW v Johnson*, 326 U.S. 120 (“WOW”):

“... [T]he...Commission's [FCC's] power of granting, revoking and transferring licenses involves proper application ... that determine "public convenience, interest, or necessity."...[T]he Nebraska [state court] decree orders...the return of the [FCC] license.... Equally does it prevent WOW from opposing a return.... These are restrictions...upon the licensing system which Congress established.... [B]y controlling the conduct of parties before the ... Commission, the court below reached ...into matters that do not belong to it.... Accordingly, the judgment is reversed....”

Citing *WOW*, the FCC Commission stated in *In re Arecibo*, FCC 85-462, 101 F.C.C.2d 545:

“... [I]n...*WOW v. Johnson*, supra.... [w]e understand the Supreme Court to have held that, in taking steps to place a matter before the Commission, a court can neither prohibit interested parties from making arguments to the Commission concerning the merits of the matter nor infringe in any way the Commission's exclusive, jurisdiction over licensing matters. See ... *WOW v. Johnson*, supra at 130-31. The Superior Court's actions here have not interfered with Arecibo's right to assert before the Commission any argument regarding the assignment applications, and the court specifically left to the Commission the determination of all public interest issues which might be raised by the applications.”

See also 28 USC §1498 and its origin: no one can block any US agency from using patented tech, even that may violate state law contract rights.

The above is based on The Supremacy Clause clause, Article VI of the U.S. Constitution and related exclusive federal jurisdiction and preemption. The above also assumes First Amendment law.

In sum: the FCC, and equally the NTIA, and certainly Congress, should protect, for its public-interest purposes, presentation of relevant ideas and information by interested persons, and remove any barriers. This needed government-purpose protection - *is in addition to* - private-purpose First Amendment speech and petitioning.

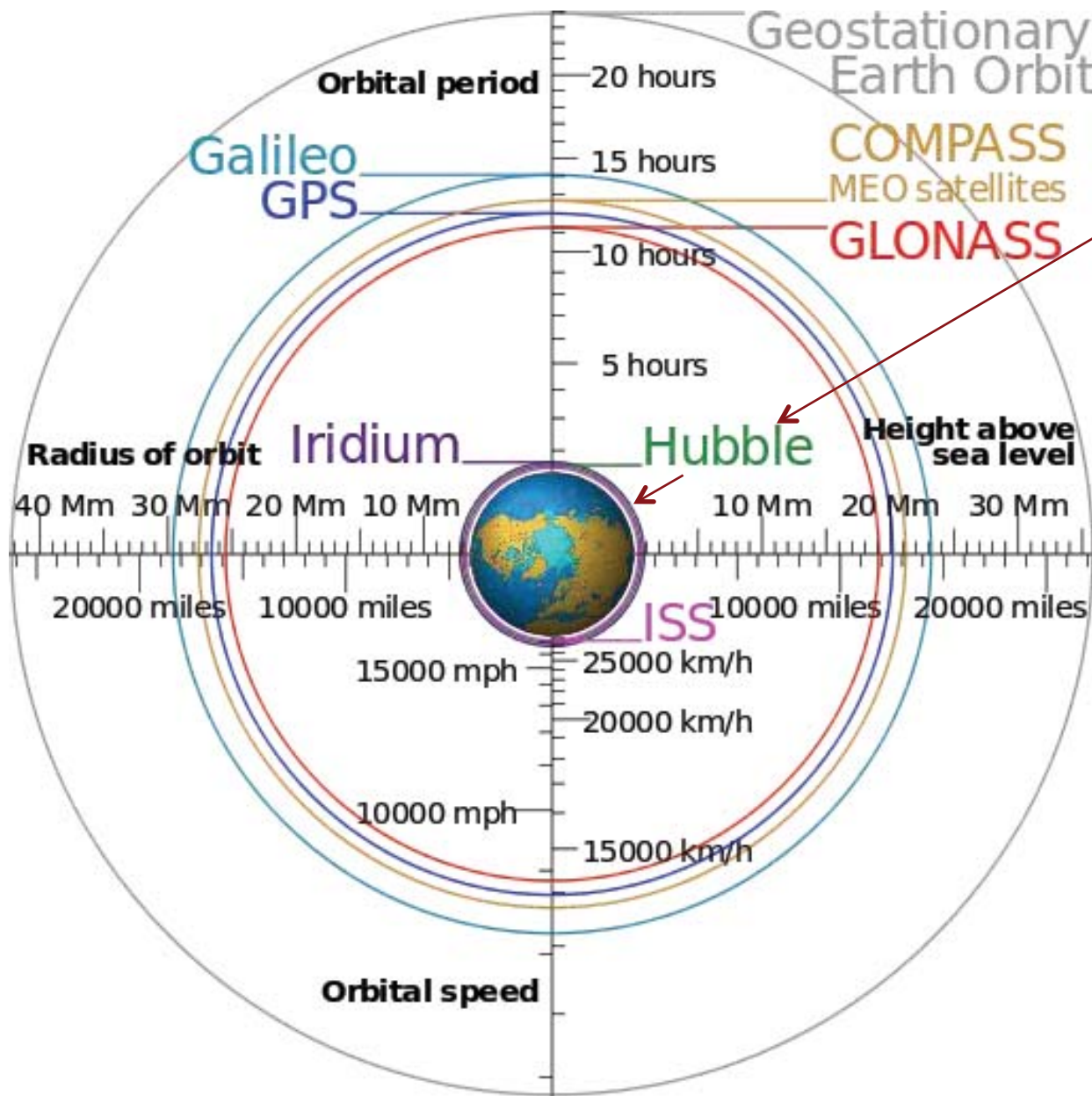
## I. Advanced Meteor Burst Radio Signaling (MBRS) – what and why

3

PNT

US PNT\* Agencies

\* Position, Navigation & Timing  
& Federal Radionavigation Plan



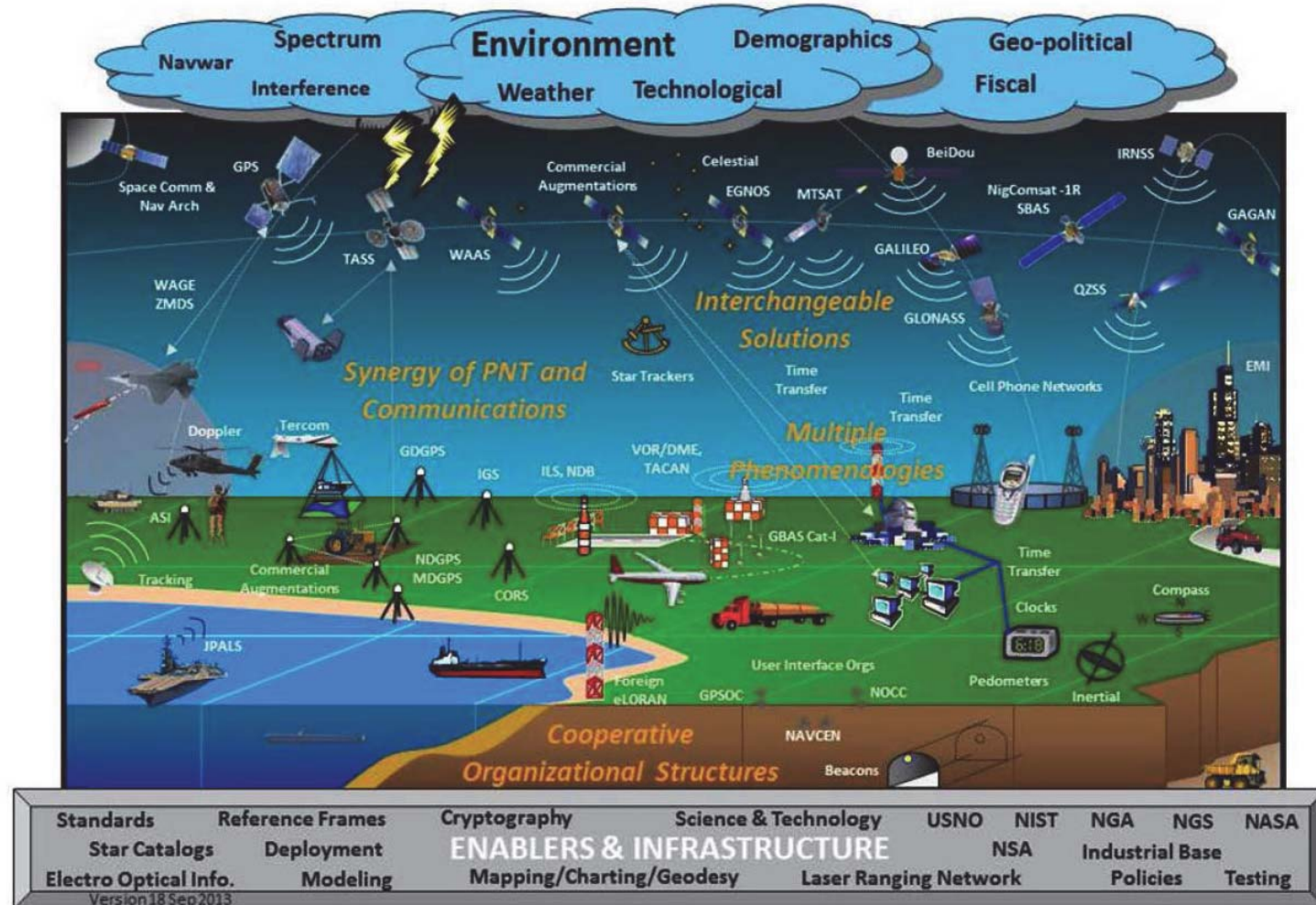
MBRS described uses meteor burst plasma trails in the range of 80-100 km above the earth (height above sea level). (Well Inside Hubble orbit shown at left, which is at about 600 km.)

There is a constant series of MBRS plasma trails, billions a day above the earth, that serve as effective "smart antennas" for 25-55 MHz +/- range radio spectrum signaling.

This can provide alternative precise PNT to GPS-GNSS, and one- and two- way communications as well.

In addition, it can provide faster time transfer, and more secure encryption, versus other methods, which is critical for data networks for critical infrastructure and services.

From the 2015 Federal Radionavigation Plan: see next page.




**Figure 6-1 National PNT Architecture (2025)**


The [advanced MBRS](#) proposed herein would provide a continent-wide foundation of [Position, Navigation and Timing \(PNT\)](#) functionality that augments, but also operates in fully independent mode, to the space-based and terrestrial PNT functions depicted above. It also would provide increased MBRS encryption to substantially improve security, and be more robust and resilient in any space or terrestrial attack versus.




<http://www.navcen.uscg.gov/pdf/FederalRadionavigationPlan2014.pdf>

## 2014 Federal Radionavigation Plan [marked excerpts]

 Ashton B. Carter  
 Secretary of Defense  
 Date: MAY 19 2015

 Anthony R. Foxx  
 Secretary of Transportation  
 Date: 2-23-15

 Jeh C. Johnson  
 Secretary of Homeland Security  
 Date: May 5 2015

The FRP contains chapters covering Roles and Responsibilities, Policy, representative PNT User Requirements, Operating Plans, and the National PNT Architecture, as well as appendices covering System Parameters and Descriptions, PNT Information Services, and Geodetic Reference Systems and Datums. It is updated biennially, allowing more efficient and responsive updates of policy and planning information. Your suggestions for the improvement of future editions are welcomed.

While the growth in civil and commercial applications continues, PNT information provided by GPS remains critical to U.S. national security. Likewise, the continuing growth of services based on the GPS presents opportunities, risks, and threats to U.S. national, homeland, and economic security. The widespread and growing dependence on GPS of military, civil, and commercial systems and infrastructures has made many of these systems inherently vulnerable to unintentional interruption and likely targets of intentional attack on PNT services. Therefore, the U.S. must continue to improve and maintain GPS, augmentations, and backup capabilities, in order to meet growing national, homeland, and economic security requirements, civil requirements, and commercial and scientific demands.

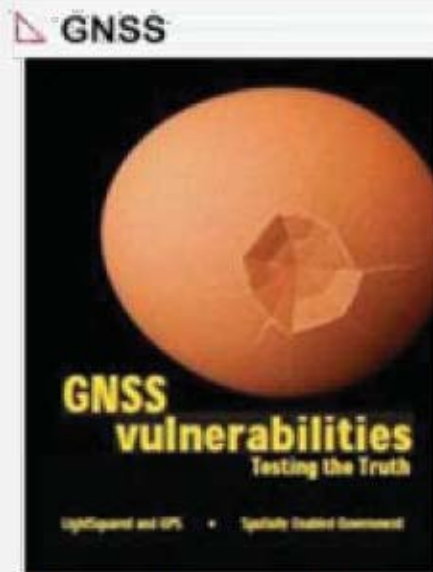
PNT services have historically been provided from ground based systems. As the full civil potential of GPS services and its augmentations are implemented, the demand for services provided by other federally provided PNT systems is expected to decrease. The USG will reduce non-GPS-based PNT services with the reduction in the demand for those services. However, it is a policy objective of the USG not to be critically dependent upon a single system for PNT. The USG will maintain backup capabilities to meet: (1) growing national, homeland, and economic security requirements, (2) civil requirements, and (3) commercial and scientific demands. Operational, economic, safety, and security considerations will dictate the need for complementary PNT systems. While some operations may be conducted safely using a single PNT system, it is Federal policy to provide redundant PNT service where required. Backups to GPS for safety-of-life navigation applications, or other critical applications, can be other PNT systems, or operational procedures, or a combination of these systems and procedures, to form a safe and effective backup. The FAA is

Real-time carrier phase differential positioning is increasingly employed by non-navigation users. Currently, this requires a GPS reference station within a few tens of kilometers of a user. In many cases, users are implementing their own reference stations, which they operate only for the duration of a specific project. Permanent reference stations to support real-time carrier phase positioning by multiple users are currently provided in the U.S. primarily by private industry. Some state and local government groups are moving toward providing such reference stations. Other countries are establishing nationwide, real-time, carrier phase reference station networks at the national government level.

For automobiles and other land navigation systems, Intelligent Transportation System initiatives seek to leverage the synergy of PNT and communications in areas like Connected Vehicle Research. As envisioned, a system of connected vehicles has the potential to transform travel through interoperable wireless communications networks. The technology will enable cars, trucks, buses, and other vehicles to “talk” to each other and road infrastructure to continuously share important safety, mobility, and environmental information. Vehicle-to-vehicle communication systems may also factor into Positive Train Control initiatives as researchers explore ways to integrate GPS into communications systems that could warn trains and cars of potential collisions at railroad crossings.

The advanced MBRS proposed herein would provide for what is underlined above: a continent-wide foundation of Position, Navigation and Timing (PNT) functionality that augments, but also operates in fully independent mode, to the space-based and terrestrial PNT functions in this plan (depicted in page above). It also would provide increased MBRS encryption to substantially improve security, and be more robust and resilient in any space or terrestrial attack versus.

# GNSS Vulnerabilities are a Major Concern



COORDINATES MAGAZINE  
March 2012



Royal Institute of Navigation

Science Technology Practice

7th ANNUAL  
GNSS VULNERABILITIES AND SOLUTIONS CONFERENCE  
18 – 20 April, 2013



U.S. Department of Homeland Security

“Maintains a central database for reports of domestic and international interference to civil use of GPS ...”

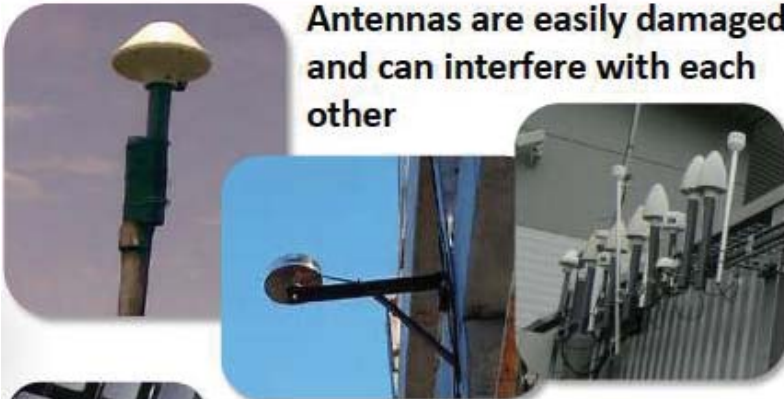
**U.S. GPS Interference  
Detection and Mitigation (IDM) Program**

**GNSS vulnerability is a growing concern in critical  
infrastructure applications**

# Everyday GNSS Outages (Unintentional)

## Mechanical, Human Error

Antennas are easily damaged and can interfere with each other



Human error in GNSS system operations



GPS cable conduit dangling in the wind



Harmonics or radiation from nearby electronics, failures or misaligned transmission equipment



Confidential © Copyright 2013

## Natural, Environmental

Lightning hits and high winds take out antennas, antenna icing



Solar flares, atmospheric phenomena



Foliage causes signal masking



14

# Everyday GPS Outages (Intentional)



## Jammers and Spoofing



Jammers



\$55 Ebay



\$83 GPS&GSM



Spoofing

## Cheap jammers to sophisticated spoofing

### Signal Characteristics of Civil GPS

Devices which claim to jam or "block" GPS are widely available through a number of web and online entities. The cost of these devices ranges from a few tens of dollars to several hundred. The cost does not seem to correlate with the claims of the purveyors of these devices regarding the range and effectiveness of the product in question. The range ranges from a few meters to several tens of meters are advertised, but it will be shown that the effective ranges are significantly greater. Civil GPS true power consumptions range from a fraction of a Watt to several Watts.

## Software attacks

### GPS Software Attacks

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### ABSTRACT

While the Global Positioning System (GPS) has grown from a limited purpose positioning system to a ubiquitous critical infrastructure, it is also the most vulnerable.

While GPS is commonly known for personal navigation, it is also used for mission-critical infrastructure, defense, and scientific research.

In this work, we systematically map out a larger attack surface by viewing GPS as a computer system. Our surface includes higher level GPS protocol messages than previous work, as well as the GPS OS and downstream dependent systems. We develop a new hardware platform for GPS attacks, and develop novel attacks against GPS infrastructure. Our experiments on consumer and professional-grade receivers show that GPS and GPS-dependent systems are significantly more vulnerable than previously thought. For example, we show that remote attacks via malicious GPS broadcasts are capable of bringing down up to 30% and 20% of the global CORS navigation and NTRIP networks, respectively, using hardware that costs about the same as a laptop. In order to improve security, we propose systems-level defenses and principles that can be deployed to secure critical GPS and dependent systems.

## I. Advanced Meteor Burst Radio Signaling (MBRS) – what and why

4 - 7

# What is MBRS and Advanced MBRS

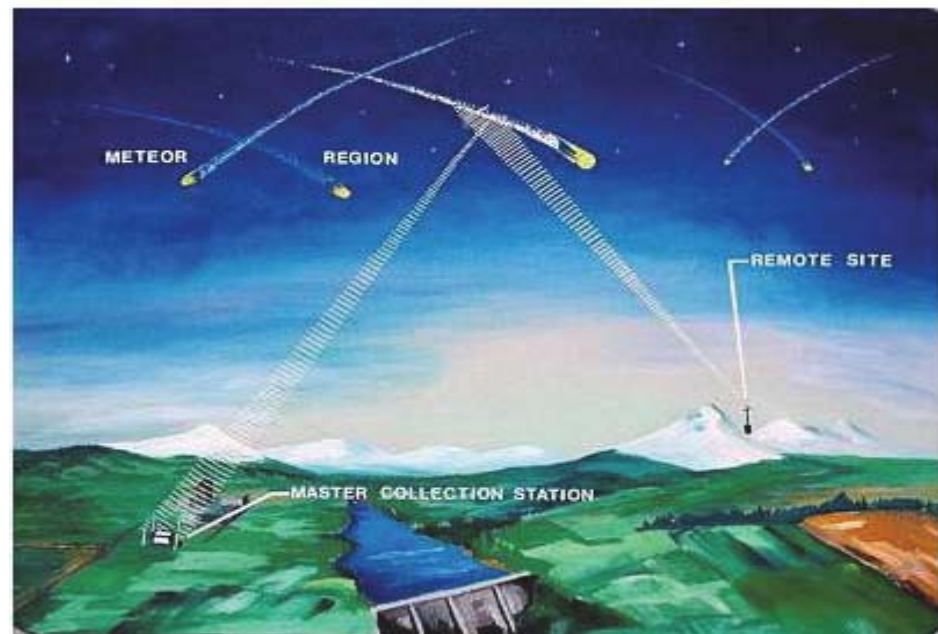


The National Water and Climate Center (NWCC) has developed efficient and highly effective technology to provide the data needed for water supply, climate, analysis, and conservation planning. NWCC acquires additional data sets that are needed from other networks and designs local data networks and sophisticated national networks. NWCC operates a variety of networks that use different data acquisition technology. We offer our expertise to others through documentation, training, partnership, on-site assistance, and participation in professional forums. Briefly, some of the types of data acquisition technology that are currently established are:

Note. NRCS SNOTEL shows MBRS is successful for NCRS's critical purpose. Advanced MBRS discussed herein may, under on plan, complement SNOTEL in a 'partnership' – see left.

### Meteor Burst Communication Technology

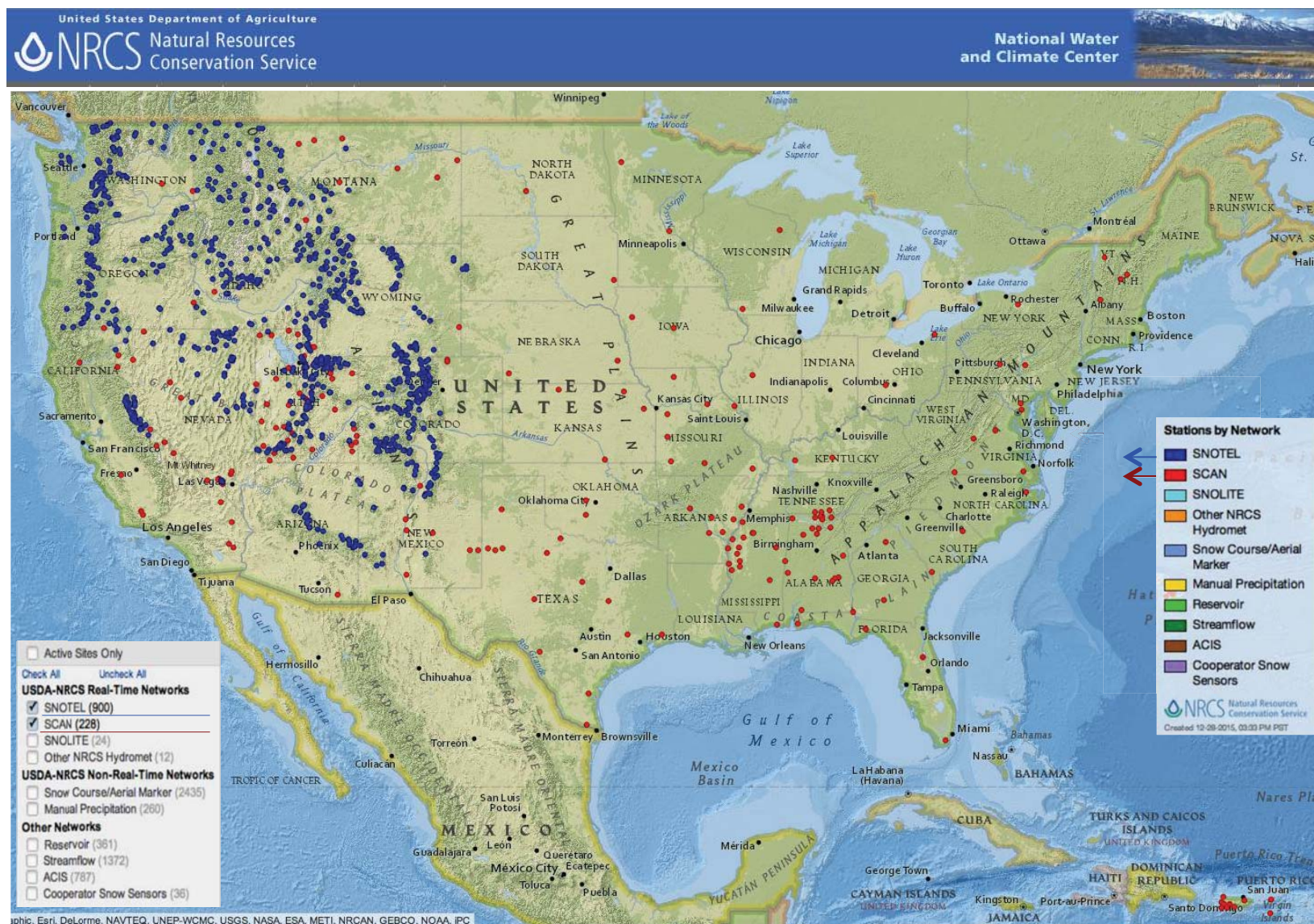
Meteor burst communication was discovered by the military in the 1950's. NRCS implemented this technology and developed SNOTEL in 1975. Meteor burst communication uses the billions of sand sized particles (1 gram or larger) that burn up in the 50 to 80 mile high region of the atmosphere to relay radio signals back to the earth. This technique allows communication to take place between remote sites and a master station up to 1200 miles away. At the master station, the remote site data is checked for completeness. If so, an acknowledgment message, returning over the same path, tells the remote site not to transmit again during this polling period. The entire process takes place in less than a tenth of a second. Meteor burst communication has proven to be extremely reliable. From the master stations, the data are sent via telephone line to the NWCC Central Computer Facility.



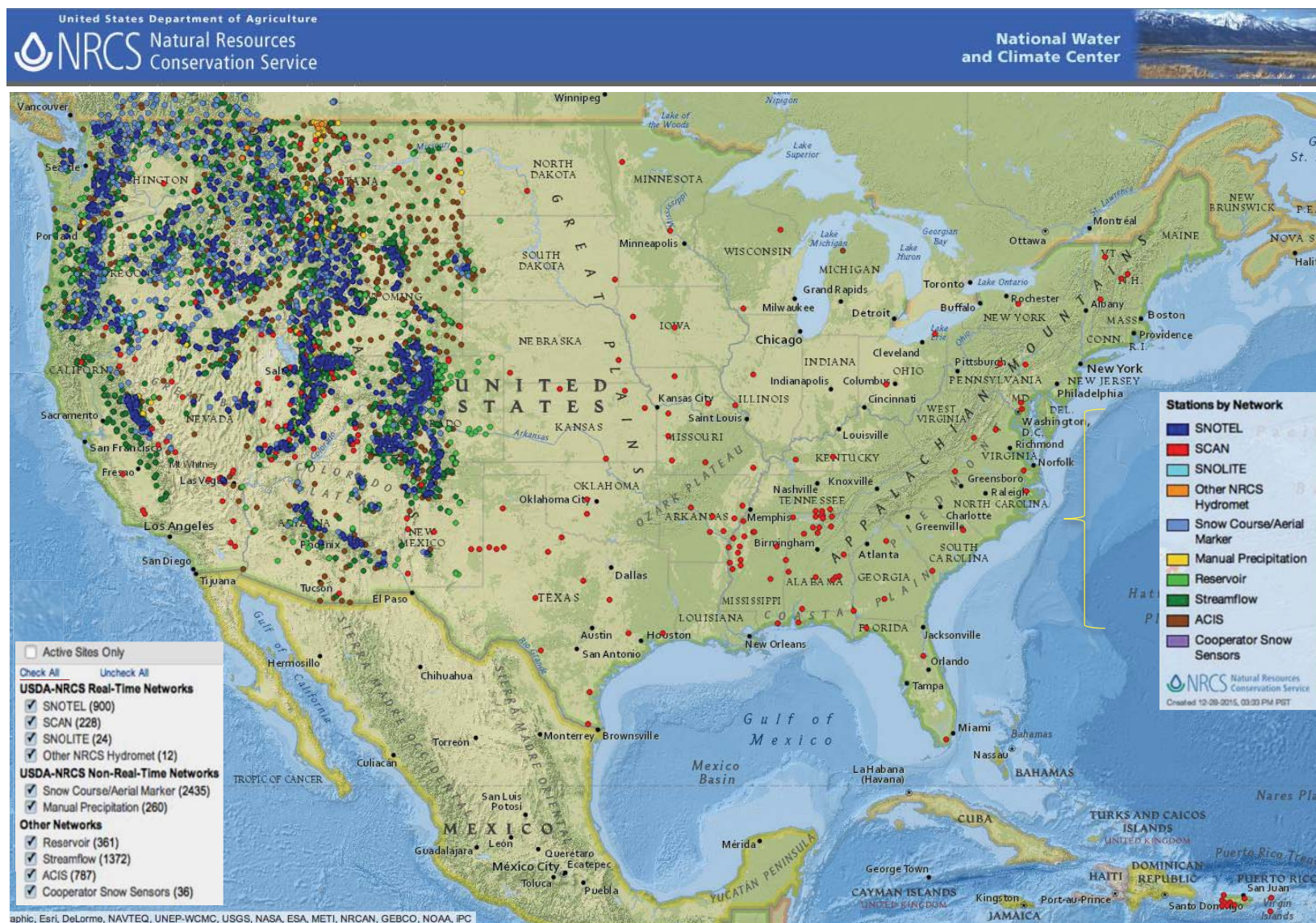
### Electronics Maintenance Facility

The NWCC operates a SNOTEL electronics maintenance facility that maintains a fully functional complement of modular SNOTEL components that can be sent overnight, worldwide if a component fails. The facility also repairs data acquisition systems sent in from the field, designs custom interface boards, tests sensors, keeps abreast of latest technology, and provides answers to technical questions related to data acquisition technology.

Note: Above excerpts are from: <http://www.wcc.nrcs.usda.gov/publications/Briefing-Book/bb25.html>. Maps of NRCS SNOTEL remote stations are on following pages.



Note: This shows the current MBRS-based SCAN and SNOTEL stations (SCAN is described below). SNOTEL - 900 stations. SCAN - 228 stations (see legend bottom left). The next slide displays all of these NRCS "Networks" stations in the legend. The map was generated at the NRCS online interactive mapping tool, on 12-28-14. I unchecked "active sites only," since doing so showed a few more stations (those apparently not "active" at this date).



Note: This shows the **current MBRS-based SCAN** and **SNOTEL** stations, and all other of these NRCS “Networks” stations in the legend. *Cost effective advanced MBRS* as described herein could serve all these, and tens of thousand or more, stations to monitor and protect the environment, get data for better prediction and regulation, etc. The map was generated at the NRCS online interactive mapping tool, on 12-28-14. I unchecked “active sites only,” since doing so showed a few more stations (those apparently not “active” at this date).

## Management of Natural and Environmental Resources for Sustainable Agricultural Development

### Proceedings of a Workshop

November 2008



United States  
Department of  
Agriculture



Natural Resources  
Conservation Service



WMO OMM  
World Meteorological  
Organization  
Agricultural Meteorology  
Division



Over the past two decades, there has been an increasing awareness of the potential damages that climate change, air and water pollution and inadequate natural resources management could induce upon human health, natural ecosystems and the economy. To address these concerns, considerable emphasis has been placed on sustainable development by many countries and international organizations. Accordingly, sustainable agricultural development has become a

### The U.S. Department of Agriculture's Natural Resources Conservation Service Soil Climate Analysis Network

There is a need for a national network that provides near real-time soil moisture and temperature data combined with other climate information for use in natural resource planning, drought assessment, water resource management, and resource inventory. In 1991, a 10-year pilot project was started to test the feasibility of such a network. Initially, 21 stations were established in the pilot project. Over the span of the project, an array of above ground and below ground sensors were tested along with a unique meteor burst communication system. This pilot led to the development of the Soil Climate Analysis Network (SCAN). The network now has 115 stations, of which most have been installed since 1999, located in 39 states. The stations are remotely located and collect hourly atmospheric and soil moisture and temperature data that is made available to the public via the Internet. Future plans for the network include locating new stations on benchmark soils, increasing the number of stations, making data summaries more user-friendly, and increasing data quality.

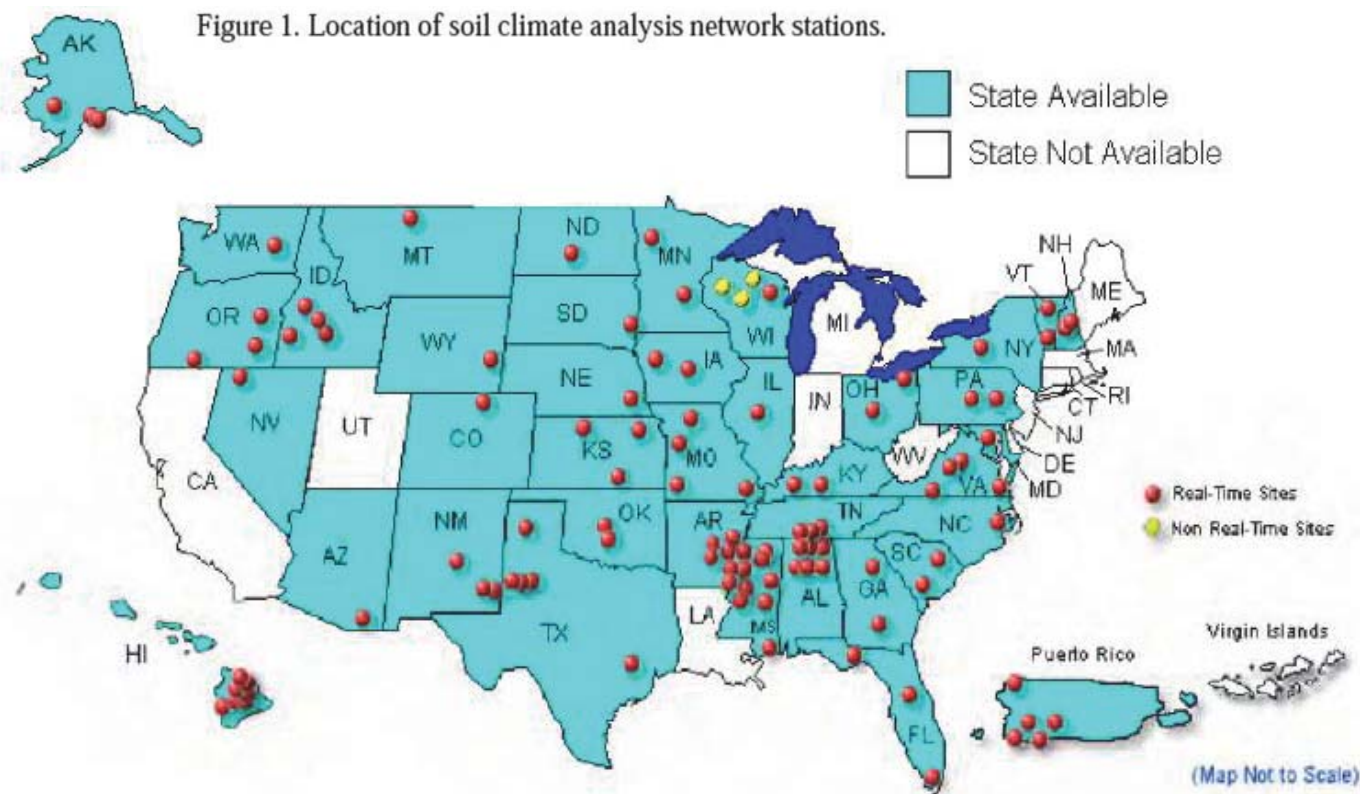
Note: This was a major international conference on the topic at top left- and, now even more critical, with increasing evidence of "global warming" in high probability to stop the causes and effects.

US DOA NRCS presented its **meteor-burst** communication (an aspect of MBRS) **SCAN** system and expansion plan.

**SCAN** is like **SNOTEL** – both use MBRS and both are by DOA NRCS.

The advanced MBRS presented in these slides can assist and expand **SCAN** and **SNOTEL**, among other federal and federal-goal programs.

Figure 1. Location of soil climate analysis network stations.



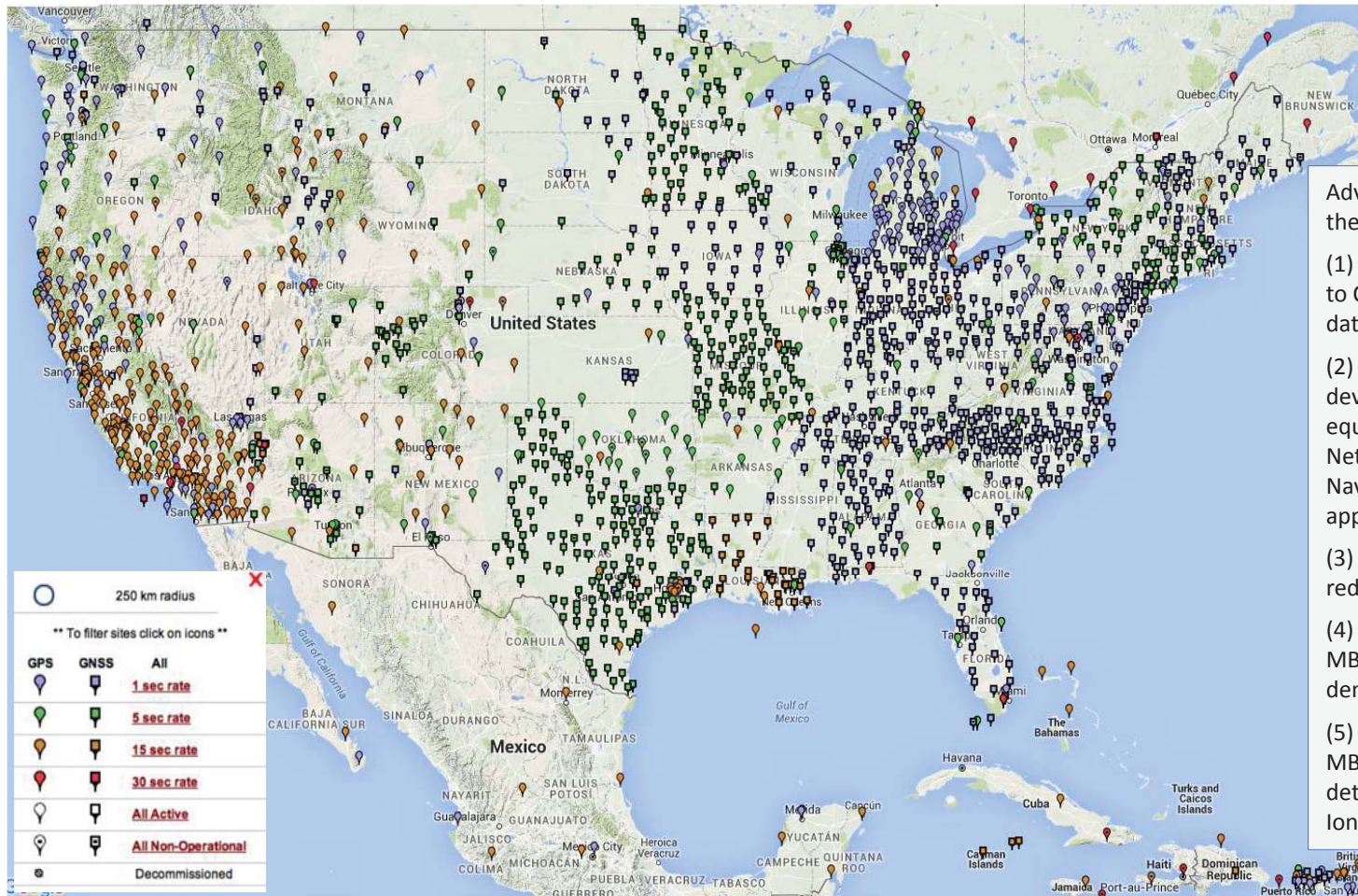
The advanced MBRS presented in these slides can assist with this planned\* expansion of MBRS-based SCAN, including by the proposed public/ private-nonprofit / private “partnerships”, and strong economic viability.

Federal agencies involved, here- DOA, would primarily provide radio spectrum and some core wireless network facilities, and the private sides would provide Capex and Opex capital, and other recourses needed.

The current network is comprised of 113 stations, which are located in 39 states (Figure 1).

Under the proposed full implementation of SCAN, more than 1,000 new remote sites would be added (USDA-NRCS, 2004). This would be accomplished by (1) integrating information from existing soil-climate data networks and (2) establishing new data collection points through partnerships with Federal, state, local, and tribal entities. This design will support natural resource assessments and conservation activities well into the 21st century; however, the full implementation of SCAN is dependant upon additional funding.

\* Above from the proceedings of the 2006 conference. A map of the current, end-2015, SCAN stations is on a slide several slides above.



- (1) provide wireless data links to CORS stations to transmit data to the networks involved,
- (2) deliver CORS data to rover devices with nRTK GPS-GNSS equipment (in Real-Time Networks) for precise Position, Navigation and Timing applications (pPNT),
- (3) more secure wireless, and redundancy, and lower cost,
- (4) use the CORS data for MBRS ipPNT (GPS- independent pPNT).
- (5) Improve CORS data by MBRS multistatic radar detection and prediction of Ionospheric conditions.

The CORS network is a multi-purpose cooperative endeavor involving government, academic, and private organizations. The sites are independently owned and operated. Each agency shares their data with NGS, and NGS in turn analyzes and distributes the data free of charge. As of August 2015, the CORS network almost 2,000 stations, contributed by over 200 different organizations, and the network continues to expand.

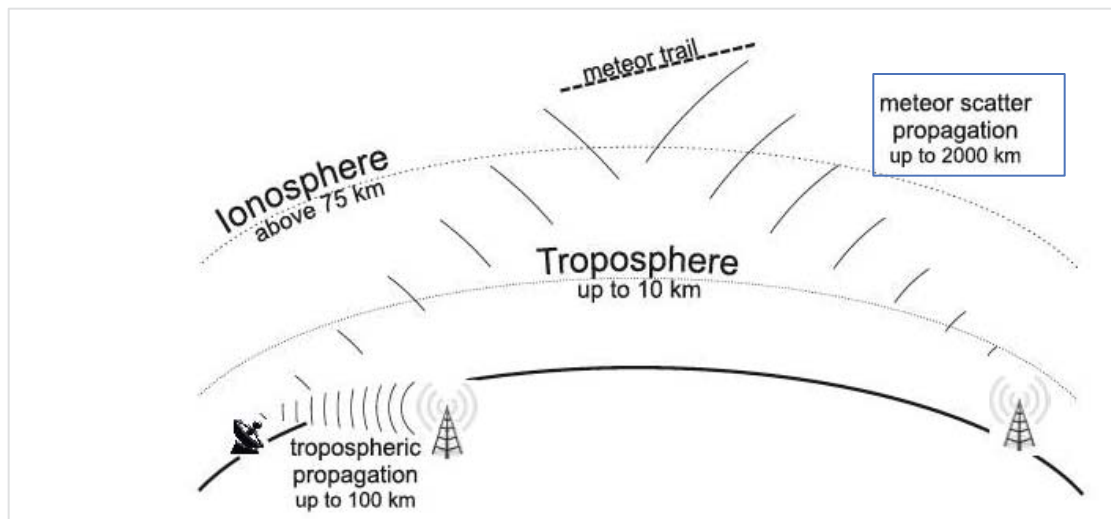


Fig. 1.— The principle of meteor scatter phenomenon.

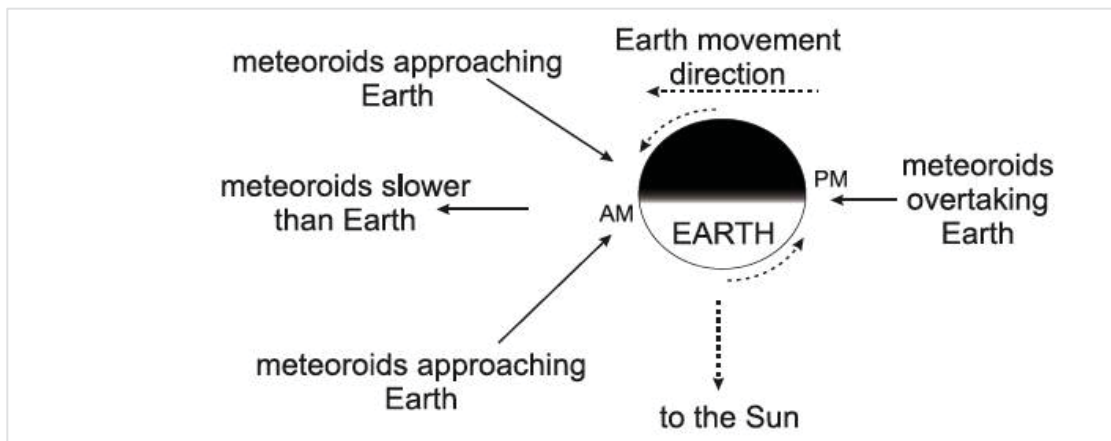


Fig. 2.— The visualization of the Earth in meteoroids environment.

Note: Copy at: <http://arxiv.org/pdf/1505.02366.pdf> / Other depictions of MBRS elements are provided below.

Note: The most complete work on “traditional” MBRS is:

**Meteor Burst Communications: Theory and Practice**, Donald L Schilling, editor. Wiley, 1993. See following pages.

Traditional MBRS is all that can be found in coherent form in public records, even current papers.\* I have found indications of “advanced” MBRS in development in China and Russia, but the details do not appear to be publicized, and the authors and institutions do not respond to my inquires. In any case, I believe I have a more full and effective approach outlined herein.

The advanced MBRS outlined herein probably exceeds 1,000-fold in total performance and value as compared to “traditional” or modestly augmented MBRS found in most all papers on MBRS.

This is supported by assumptions using best-available MBRS system parameter data and what-if calculations.

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\* E.g.

[http://www.ijetie.org/articles/IJETIE\\_201518006.pdf](http://www.ijetie.org/articles/IJETIE_201518006.pdf)

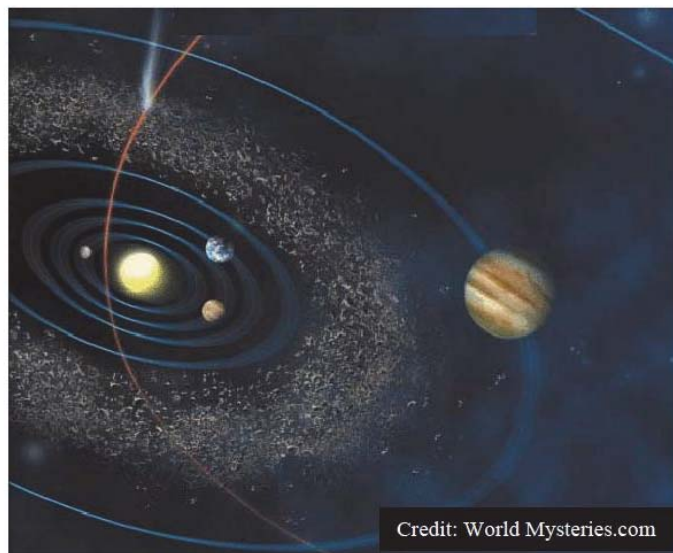
## Detection of Meteors by RADAR

© Dr David Morgan 2011

### Meteors

What are they – where do they come from?

There are two main sources of small particle debris that constitute meteoroids....asteroids and comets.... [Figure 2.1](#).

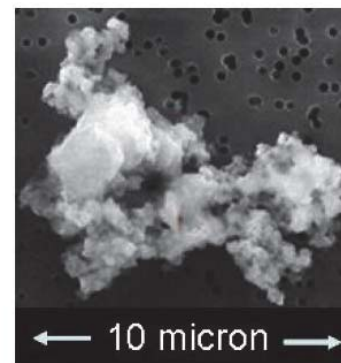


[Figure 2.1](#)

Comets and Asteroids as the source of Meteoroids

### Meteor trails

Meteor trails are formed when tiny particles, maybe the size of a grain of sand or smaller (see [Figure 2.3](#)) impact the Earth's upper atmosphere at a height of around 90km and generate a



[Figure 2.3](#)

Example of a Meteoroid Particle

strong shock wave in the air. There is a huge temperature differential generated across the shock boundary and the radiant heat vaporizes the surface of the particle. This causes the ablation of the particle and ionization of the atoms of the material....

The vaporized material and ionized air play a large part in reflecting electromagnetic waves at radio frequencies – thus enabling their detection by [VHF](#) radar.

Here we examine the way the incident radar wave interacts with the ionized trail. In Figure 3.3 we see the wave approaching a stream of ionized particles represented by a mix of positive ions, negative electrons and neutral molecules. It is only the electrons that respond significantly to the electric field in the incident wave. The ions are heavy and do not move a significant amount and play little part in re-radiation of the pulse. The neutral molecules carry no net charge and cannot interact with the wave electric field. The strength of the returned signal is dependent on...electron density in the trail... this varies with time, so does the signal strength.

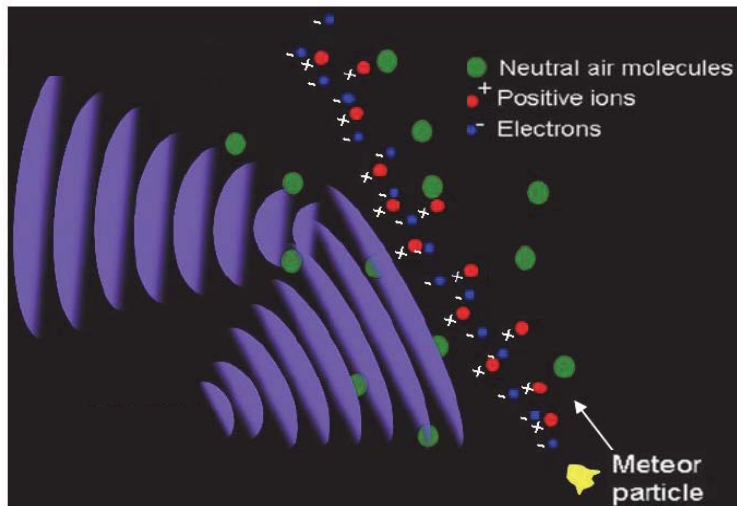


Figure 3.3 Wave interaction with the Ionization Trail

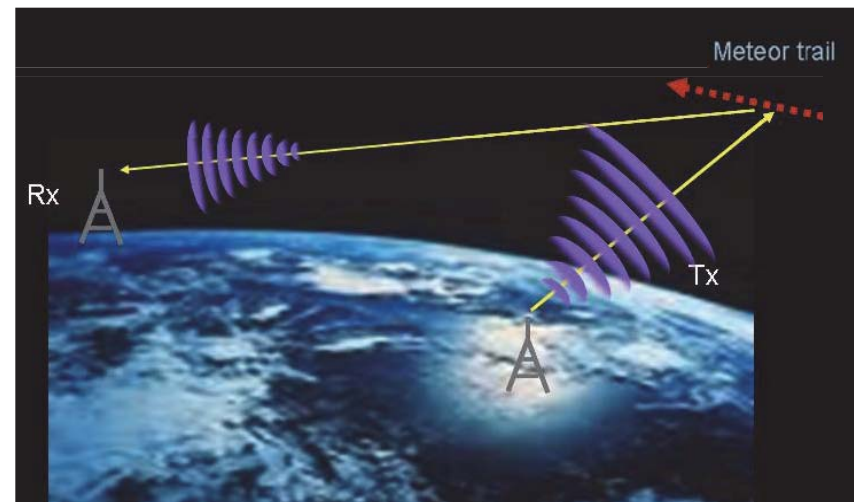
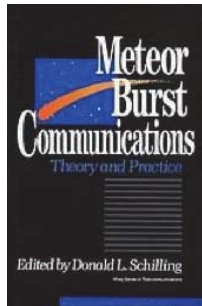


Figure 4.4 Reflection from a meteor trail

*Meteor Scatter* communication systems are highly efficient in its use of the radio spectrum. Radio frequencies are a scarce commodity and the increasing appetite for information demands economical use of the radio spectrum. Because in a large service area different users are "served" by different meteors, interference between the users is virtually ruled out, even if the same frequency is used over a very large area. In this way, the whole of Europe can be served by using only one or two channels, dependent upon the configuration of the communication network.

Note: The advanced MBRS outlined herein probably exceeds 1,000-fold in performance and value as compared to “traditional” or modestly augmented MBRS found in most all papers on MBRS, including the most advanced MBRS described in this 1993 book.



**Meteor Burst Communications:  
Theory and Practice**

Donald L Schilling, editor. Wiley, 1993

Part 1 below is from Mr. Shilling's oral history

Part 2 below has experts from the book

Part 1 From: [http://ethw.org/Oral-History:Donald\\_Schilling](http://ethw.org/Oral-History:Donald_Schilling)

I co-authored 12 texts and more than 200 papers. I advised more than 75 Ph.D. students, many of who wrote their Ph.D. dissertations on CDMA related topics. In the 1960's I was involved with adaptive delta modulation, a voice digitization technique which was used by the military at that time; it is still used to perform analog to digital conversions.... I did the work initially for NASA, then after NASA I did it for the Army, and then for several other government agencies.

After the adaptive delta modulator I became involved in **meteor burst communications**, which was a wireless system used to transmit signals beyond the line of sight, using the meteor channel. Meteors are formed all the time, and we bounced our waves off of the meteors. **If you do it right, you can get continual** voice. A lot of this was done for the Air Force in Anchorage, where they transmitted between Anchorage and Kozebue, which is a city in Alaska right off the Russian border across the Bering Sea. It was a lookout station, and there was no real ionosphere to communicate back and forth, so they communicated off the meteors. We built the equipment and **demonstrated** that **continual** voice could actually be achieved if it was done properly. We had an adaptive system.

I **edited** a textbook for ... **Wiley** on Meteor Burst Communications, which dealt with that whole area.

Part 2

....Today, we know that to be true because man has walked on the moon, space travel has become... common..., high-energy lasers are used in the medical...and other areas, communication satellites carry voice and data circuits to all points of the globe, and there is meteor burst technology. **Meteor burst technology?** [“MB”] What's this? Are we bursting meteors? No, just another communications medium...until the early 1970s...virtually ignored.

Discovered in 1935 by a gentleman named Skellet, the technology was considered antediluvian in face of the then current communication systems.... Skellet found that when a meteor entered the earth's atmosphere, the denser air caused the meteor to heat up and eventually burn, creating an **ionized trail**. He discovered that the ionized trail could be used to **bounce a radio signal back to earth**. Scientists have known for decades that the earth is continually bombarded by meteors.... **One hundred billion meteors** have been estimated to enter or pass through the **earth's atmosphere** in a **24-hour** period.

From the 1950s through the 1970s, meteor burst technology was studied and actual tests were conducted to determine the feasibility of using the meteor trails to an advantage. The result of that research produced some interesting information....

Ionized trails were found to have a lifetime of only a few tenths of a second, creating the need for rapid exchange of communication. The transmission rate had to be very fast (a **burst of data** if you will) to take advantage of the ionized trail. Hence the term “**meteor burst**” was coined. [U]ntil the availability of integrated solid-state micro-computers, meteor burst as a communication medium was not considered practical except for slow-speed data.... \* \* \* \* These short-lived... signals, or meteor bursts, may last from several milliseconds to many seconds.

Signal duration depends on trail line density, initial radius, diffusion rate, electron attachment and the state of upper atmospheric winds. Digital communications is possible during these brief, intermittent meteor bursts, thus forming the basis for an [over-the-horizon digital radio link](#). Since persistent meteoric ionization useful for [trail-scatter occurs](#) between [80 and 120 km above](#) the [earth's](#) surface, maximum propagation distances of [2400 km](#) are possible. The maximum usable distance for communications, however, is generally below [2000 km](#) because of earth blockage, terrain obstructions, and antenna pattern ground tuck. The time dependence of the trail-scattered RSL depends on the electron volume density in the meteor trail as well as atmospheric parameters.... \* \* \* \*

The [Alaskan Air Command](#) was the first to install a high-powered, 8kb voice-synthesized MB system as an operational communication medium. Uniquely designed, it supports the operational requirements for Air Sovereignty in Alaska. Other uses may come to light that will parallel those of the Alaska Air Command. However, there will always be a need for inexpensive data systems within the military and in industry. Currently, [NORAD](#) is [testing](#) a C3 meteor burst network that will connect the Continental United States, Alaska and Canada.

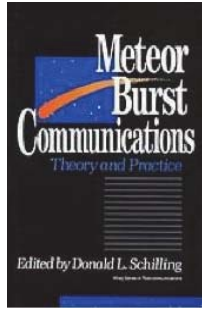
The Alaska National Guard recently installed a [MB](#) system that ties the headquarters to remote locations throughout the state. Again, the [cost](#) of acquiring a [MB system](#) is [considerably less](#) than that of other systems, [especially in](#) the Alaskan [environment](#). Other countries are now looking into the benefits of a MB system for specific applications, applications where [great distances](#) are involved and civil engineering support is too costly for other [remote](#) systems. A MB system has been installed between Sondres- trom AB and Thule AB, Greenland. The north-south link operates between 45 and 104MHz. The system is a test bed to investigate performance during polar cap absorption (PCA) events.  
...Popular Mechanics that described a MB system for truckers....

In the [tactical arena](#), small portable transceivers could be used by the military in a variety of applications such as resupply nets, status of forces nets, [intelligence nets](#), and others. The [Navy](#) could make use of a MB unit that was released under water and brought to the surface by [buoy](#). This application would enable communications while [minimizing detection](#). An [oil platform](#) out in the middle of a sea is the ideal application for MB. [Red Cross and Civil Defense](#) organizations could use [portable MB](#) systems to provide logistic support during [natural disasters](#) such as [earthquake](#), [flood](#), and [fire](#). Alarm systems, emergency or logistical networks, and similar systems could be provided in [remote](#) locations at [a fraction of the cost](#) of comparable systems. [Anywhere there is a need for data](#), MB is an [inexpensive alternative that warrants consideration](#). The applications are limitless and await only the imagination of the far-sighted.... \* \* \* \*

It is true that faster is better in terms of system processing times.... However, there are applications where "instant" is not part of the vocabulary. The Alaska SNOTEL net is a good example. Meteorological information is required on a regular basis; however, it is collected over a 24-h period. A slow data base update is acceptable and is tailored to the data collection requirement. The prerequisite for that system is that the data must get through in a timely manner....

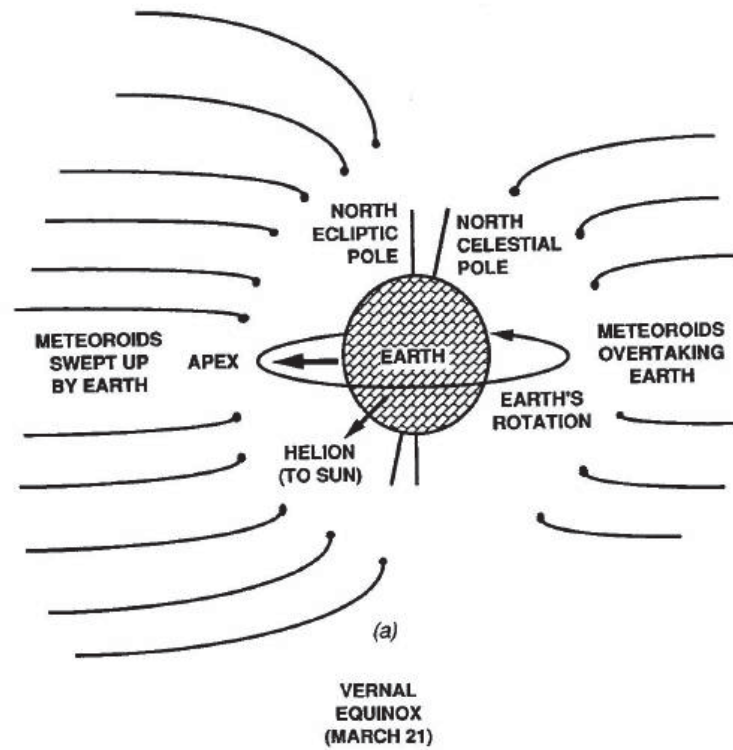
One only need analyze the [basic information requirement](#), that is, life-cycle and time-to-live needs, to make decisions in choosing a baseline communications medium. Immediate update is not always the best answer to an equation.... In spite of the popular demand for more speed, systems like meteor burst still fill special application needs. Certainly, [MB systems can be designed to perform as quickly as other systems through the use of new products now available](#) in today's market.

[In terms of cost, survivability, and intrusion resistance, meteor burst is hard to beat](#). Furthermore, it has that special Buck Rogers mystique... [how else MB can be used](#).

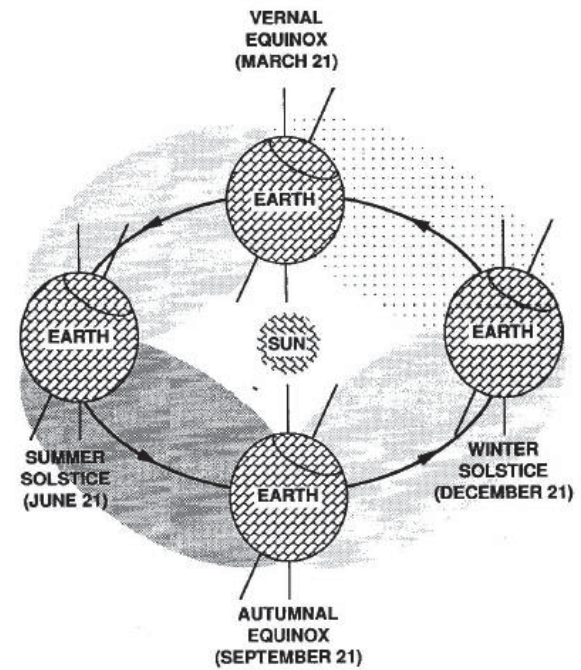


The following depictions are also (as are the introductory text excerpts above) from the book: Meteor Burst Communications: Theory and Practice . Donald L Schilling, editor. Wiley, 1993

The advanced MBRS outlined in this PPT would have more advanced master base station and remote radios that are at issue in the text above and indicated by some of the drawings below.

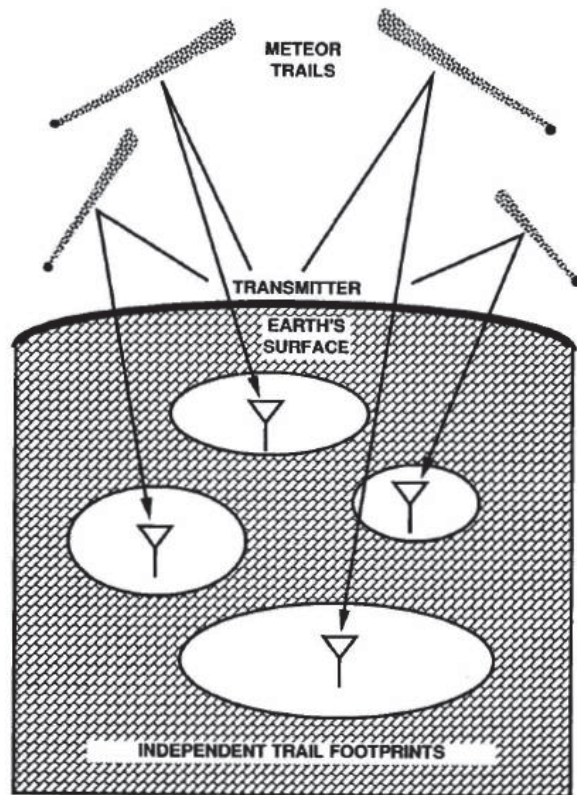


Diurnal variation in meteor rate



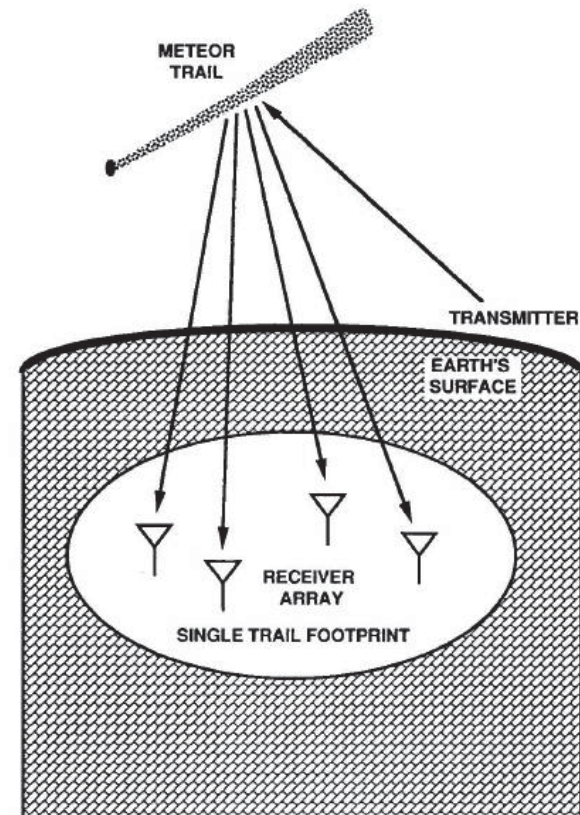
NOTE: CHANGES IN METEOROID ORBITAL DENSITY ARE MORE GRADUAL THAN SHOWN

Seasonal variation in meteor rate



(a)

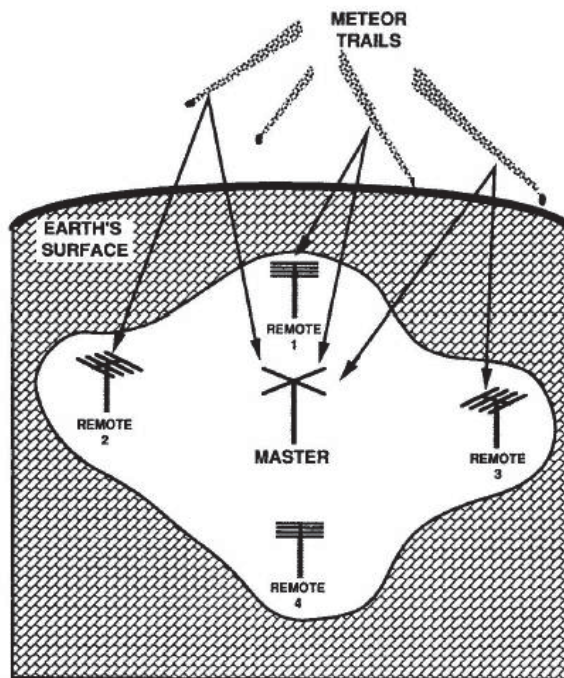
Spaced receivers in unique footprints



(b)

Closely spaced receivers in common footprint

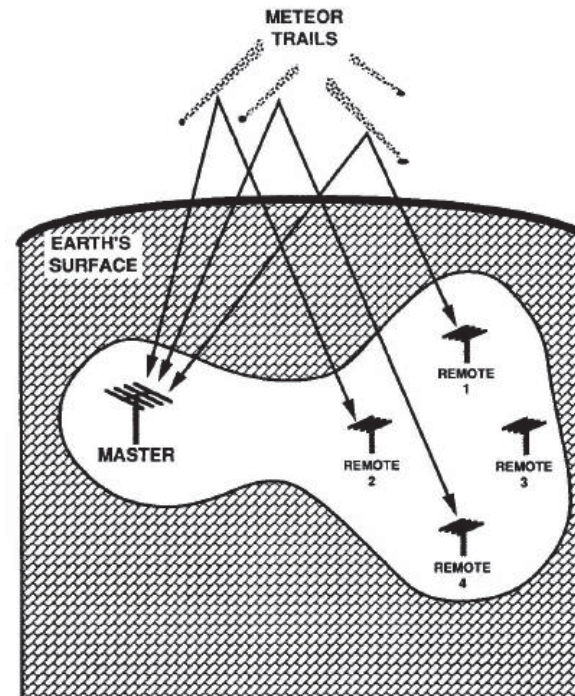
Remote radio antennas in sufficiently close proximity can be linked and synchronized to improve signal to noise ratios, and to have more meteor-trail events (in '(a)') and longer time per event (in '(b)'). Each remote radio can also have phased receiver/ antennas, as explained on one slide herein from an engineer at the KAIRA radio facility.



(a)

Figure 3.16 (a) Centrally-located master station

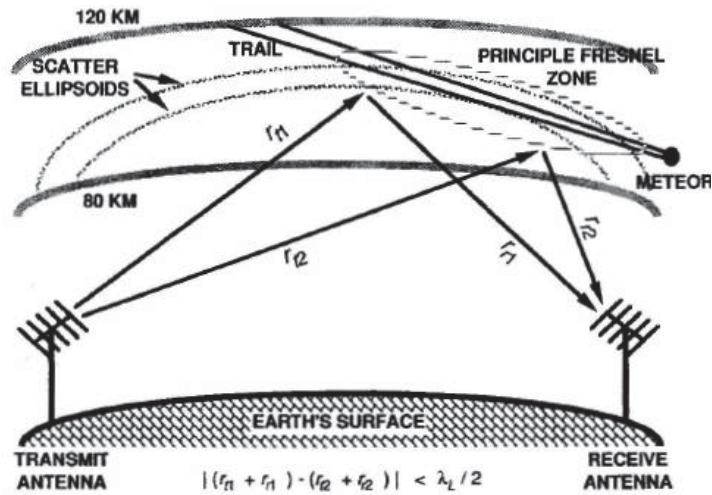
Typically, for a base station well inland to cover in all or many directions. With base station antenna arrays, the array could simultaneously cover in many directions.



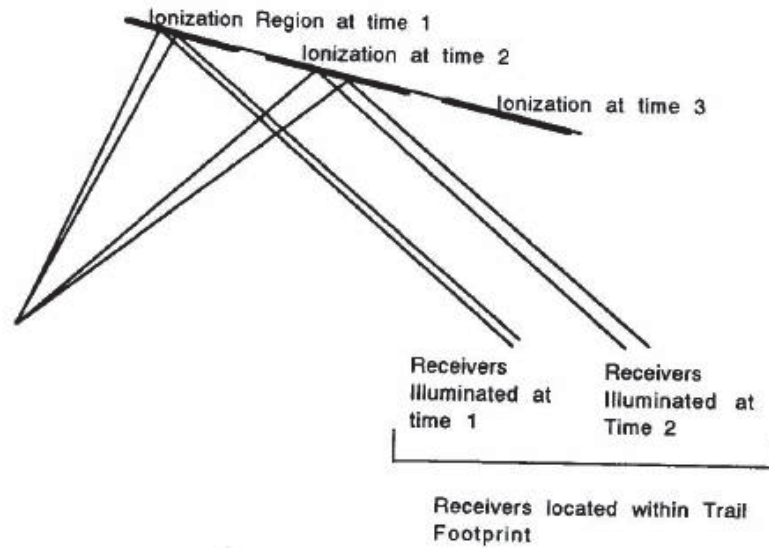
(b)

Figure 3.16 (b) Stand-off master station

Typically, for a base station on or near a coastline or other territorial border to cover offshore or beyond the border (with any permissions needed by another jurisdiction).



Link geometry for meteor trail-scatter



Motion of the ground illumination region due to trail formation and decay

# Coded continuous wave meteor radar

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## Abstract

The concept of coded continuous wave meteor radar is introduced. The radar uses a continuously transmitted pseudo-random waveform, which has several advantages: coding avoids range aliased echoes, which are often seen with commonly used pulsed specular meteor radars (SMRs); continuous transmissions maximize pulse compression gain, allowing operation with **significantly lower peak transmit power**; the temporal resolution can be changed after performing a measurement, as it does not depend on pulse spacing; and **the low signal to noise ratio** allows **multiple geographically separated transmitters to be used in the same frequency band** without significantly interfering with each other. The latter allows the same receiver antennas to be used to receive multiple transmitters. The principles of the signal processing are discussed, in addition to discussion of **several practical ways to increase computation speed**, and how to optimally detect meteor echoes. Measurements from a campaign performed with a coded continuous wave SMR are shown and compared with two standard pulsed SMR measurements.

The type of meteor radar described in this paper would be **suited for use in a large scale multi-static network of meteor radar transmitters and receivers**. .... For example, a continuous transmission **would result in 14 dB of increased signal processing gain** when compared to a pulsed system with a duty-cycle 25 of 4.4%. This additional gain can be either used to increase the fidelity of measured signals, or to reduce the peak transmit power requirements of a meteor radar system, in order to e.g., reduce the cost of a radar system....

The main advantages of a coded CW SMR are: **(a)** it can operate with less peak power, **(b)** it is suitable for a large scale multi-static radar network, **(c)** it does not suffer from the range-Doppler ambiguity problem, **(d)** there is no inherent limit to time resolution, and **(e)** it is less susceptible to false detections due to radio interference when compared with pulsed systems. The latter is possible since the pulse-like interferences would be 25 spread in range and Doppler in the decoding process. We would like to stress the suitability for a large scale-multi-static radar network. Not only would the low power transmitting systems with coded wave forms be more friendly with other radio users in nearby-bands, but also the

## Coded continuous wave meteor radar

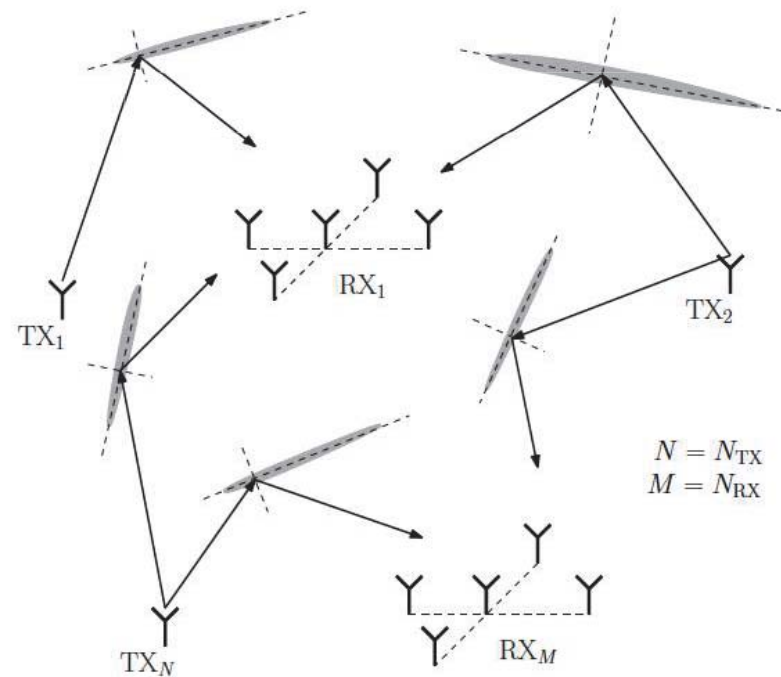
(Continued)

receiving systems could be simplified, by allowing the reception of multiple transmitters on the same antenna and same frequency. The separation of the different transmitted signals would be done by knowing the code of each transmitter site.

We have shown that **with modest CW system transmitting 30W average power**, one can obtain results not too different from those obtained with standard pulsed transmitter. Already the existing prototype used to demonstrate the principle of coded CW SMR could be used to derive winds in the mesosphere and lower thermosphere. We expect that better results, i.e., more meteor counts, could be easily obtained by increasing the transmitter power; or by adding more transmitters and receivers to measure the same volume.

## Conclusions

We have described the concept of a coded CW specular meteor radar, which can be used to build a large scale multi-static network of meteor radars, in which each single frequency receiver can listen to all of the transmitters that are within vicinity. The only restriction is that the transmitter cannot be extremely close to the receiver. Our measurement campaign results indicate that the **30W coded CW meteor radar** is nearly as sensitive as a standard pulsed meteor radar with **15kW of peak power and 770W of average power**. ...



**Figure 1. A depiction of a multi-static meteor radar network with multiple transmitters and multiple interferometric receivers.** Each transmit-receiver pair observes meteors that match the specular condition, which is usually not met between two different transmit-receiver paths, and therefore to first order, each transmit-receiver path observes an independent set of meteor trails.

## Reference 6

# NAVAL POSTGRADUATE SCHOOL Monterey, California

AD-A207 831



## THESIS

METEOR BURST COMMUNICATIONS FOR THE  
U.S. MARINE CORPS  
EXPEDITIONARY FORCE

by

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**Comment:** See underlined items. MBC can be used on [aircraft](#). This article is about what may be called first generation MBC. We plan much more advanced MBC, using much wider channels, newer wave forms, and many other improvements, some indicated above. This more advanced MBC can be used on [drones](#), especially larger ones, and those in wireless [mesh networks](#) that can synchronize antennas for gains.

The SNOTEL system was built for the Department of Agriculture by Western Union. It started operations in 1977 under the management of the Soil Conservation Service (SCS). SNOTEL collects information on snowpack conditions in the Rocky Mountains. The information is critical to water management planning in the West. The system covers eleven western states with 511 remote MBC stations. The remote stations are located in harsh, inaccessible terrain. They are unmanned and solar powered. The remote stations are controlled by two master stations located in Boise, Idaho and Ogden, Utah. The master stations collect data from the remotes each morning, when meteor activity is the strongest. Each remote sends data collected over the previous 24 hours in a 200 bit message. The collection process averages 20 minutes for the entire system.[Ref. 5 : p. 75-77]

There are several MBC systems operating in Alaska, two of them are the Alaska Meteor Burst Communication System (AMBCS) and the USAF's Alaska Air Command MBC system. The AMBCS, operating since 1977, is used by several government agencies. The Bureau of Land Management uses it to communicate with its survey teams operating in the Alaska wilderness. The SCS uses it for the same purposes as the SNOTEL system. The Federal Aviation Administration (FAA) sends weather information over the AMBCS and employs it during search and rescue operations in remote areas.[Ref. 5 : p. 78-79] The USAF system is used to provide backup connections among the Regional Operations Control Center (ROCC) located at Elmendorf Air Base near Anchorage, and 13 Long Range Radar (LRR) sites located throughout Alaska. Primary communications for these USAF organizations is provided by the ALASCOM, satellite system. The ALASCOM system is vulnerable to jamming, however, because "part of its footprint extends over the Soviet Union, and therefore,... could not be relied on during a US-USSR crisis." [Ref. 6 : p. 0567] The MBC system sends radar "tracks" from the LRRs to the ROCC and has demonstrated the ability to carry enough data to maintain a real time radar display [Ref. 7 : p. 46]. The USAF system includes a limited voice capability, allowing the ROCC to control interceptor aircraft over the MBC system. Routine dialog between a controller at the ROCC and an intercept pilot is limited to a small set of commands. A voice synthesizer added to the aircraft, has a coded vocabulary large enough to handle most of these routine commands. When conducting an intercept, the controller types a command code into the MBC terminal, and the pilot hears the command in English. The pilot is limited to acknowledging receipt or non-receipt of the message.[Ref. 7, 6]

Figure 23 shows information throughput achieved by two MBC systems. The first graph displays results from the BLOSSOM system operated by the Royal Aircraft Establishment of the UK. The BLOSSOM system operated on a 813 KM link from northern Scotland to southern England in March 1987. The system transmitted 600 watts on 46 MHz using antennas capable of covering both "hot spots." The BLOSSOM results shows both duty cycle and equivalent baud rate. At the point where 100% duty cycle was achieved, the throughput rate becomes the instantaneous transmission rate, i.e., 2400 Baud.[Ref. 29 ] The second graph comes from the USAF's research link in Greenland. This graph plots average throughput for the month of February in relation to the time of day. Again, a diurnal variation is present, and frequency dependency is also evident.[Ref. 15 : p. 3-12]

· · · tactical operations area (TOA)

The MEF commander and his immediate staff may find MBC a useful way to maintain contact with the command element while airborne into the TOA. The range of MBC increases somewhat when airborne, but with a reduction in the LPI profile.



### 33RD ANNUAL PRECISE TIME AND TIME INTERVAL (PTTI) SYSTEMS AND APPLICATIONS MEETING

Editor Lee A. Breakiro. U.S. Naval Observatory Proceedings of a meeting sponsored by the U.S. Naval Observatory, the U.S. Naval Research Laboratory the NASA Jet Propulsion Laboratory, the U.S. Air Force Office of Scientific Research, the Defense Information Systems Agency, and the U.S. Coast Guard Navigation Center. **November 2001**

.....

**Phase Radio meteor Equipment for Time and Frequency Standards Comparison**, S. Kundjukov, V. Bavykiha, Y. Koval, and Trambovetskiy, Kharkov State Technical University of Radio Electronics, Ukraine.....163 \*

**Results of Radio Meteor Comparison of Scales of the Russian UTC (SU) and Ukrainian UTC (UA) Time Standards**, V. Bavikina, Y. Koval, and A. Tkachuk, Kharkov State Technical University of Radio Electronics, Ukraine .....175

\* ..... At present the RCM, along with the methods using transportable quantum clocks (TQC) and satellite radio navigation systems (GPS, GLONASS), ensures the comparison error of the order of tens of nanoseconds. In this case the RCM surpasses the indicated methods in such characteristics as measurement productivity, self-sufficiency, operation, efficiency, concealment, and stability to ionospheric perturbations....

Parameters	Equipment				
	METKA-1	METKA-5...7	METKA-4	Phase	METKA-11
Working frequency, MHz	57.3				45.5
Impulse power, kW	50	20...40	3	10	2...4
Signal type	6 pulses code	16 pulses code	4 LFM packets	PM + DFS	PM + DFS
Signal duration, $\mu$ s	5	16x2	4x50	15x26-PM, 2x500-DFS	10x13-PM, 5x265-DFS
Comparison error, ns	300	15...30	10...30	< 1	< 1
Spectrum width, MHz	0.4	1	2.5	1	0.2

LFM = linear frequency modulation; PM = phase modulation; DFS = double frequency signal.

45 MHz,  
200 kHz,  
<1 ns. error,  
with vast of  
improvement  
left.

The investigation of the meteor channel precision characteristics, signal and equipment errors, and results of the comparison algorithm analysis and synthesis carried out recently have shown that the method's possibilities are far from having reached its limit.

## Reference 17

*Geometry of meteor burst radio propagation. Study of Phase Non-Reciprocity of Meteor Burst Channel.*

A. V. Karpov, A. I. Sulimov, S. N. Tereshin. 2015 International Siberian Conference on Control and Communications (SIBCON)

## I. INTRODUCTION

Currently, a renewed interest in the study of problems of meteor burst communication arises. This interest is associated with the development of such advanced systems as meteor synchronization and meteor encryption key distribution. Unfortunately, non-perfect reciprocity (or simply non-reciprocity) of meteor burst channel limits a performance of these promising applications. . . .

## VIII. CONCLUSIONS

The paper discussed the main regularities of phase non-reciprocity arising at synchronous two-way signal transmission in meteor burst communications. Time consuming and costly natural experiments on real meteor radio links of length over a 1000 km were replaced by computer simulation [3]. Our studies have been motivated by practical needs of the meteor synchronization systems [7-9] and systems of meteor encryption keys distribution [10-12].

. . . .

## REFERENCES

. . . .

[3] A. Karpov, S. Tereshin, J. Abrosimov, "The computer model "KAMET": The new generation version," In Proceedings of the Meteoroids 2001 Conf. Kiruna, Sweden, pp.367-370, 6-10 August 2001.

[7] V.A. Korneyev, L.A. Epictetov, V.V. Sidorov, "Time & Frequency coordination using unsteady, variable-precision measurements in meteor burst channel," In Proceedings of 17th European Frequency and Time Forum Tampa, USA, 4-8 May 2003.

[8] V.A. Korneyev, V.V. Sidorov, "Optimization of concurrent data and high-precision time transfer modes in meteor burst synchronization equipment," Proceedings of the 21st European Frequency and Time Forum (TimeNav'07), pp. 923-926, 2007.

[9] V.V. Sidorov, L.A. Epictetov, "Application of meteor burst equipment for high precision comparisons of time and frequency standards" In Proceedings of 7th European Frequency and Time Forum (EFTF'93), pp. 413-416, 1993.

[10] A.V. Karpov, V.V. Sidorov, "Method for protecting information in meteor radio channel by encryption by random natural occurrence," Russian Federation Patent No. RU 2265957, Bull. 34,... 10.12.2005.

[11] V.V. Sidorov, A.V. Karpov, V.A. Korneev, A.F. Nasyrov, "Meteor time transfer and meteor cryptography," In Proceedings of 21st European Frequency and Time Forum (TimeNav'07), pp. 315-317, 2007.

[12] A.I. Sulimov, A.V. Karpov, "Secure key distribution based on meteor burst communications," In Proceedings of the 11th International Conference on Security and Cryptography (SECRYPT-2014) Vienna, Austria, pp. 445-450, 28-30 August 2014.

**Comment:** (continued from preceding page). This meteor burst (MB) encryption can be added to many electronic-information systems, *not only* to MB communications, radiolocation, and timing. This includes Intelligent Transportation Systems (ITS) including drones, smart energy grid premises systems, other smart national infrastructure, Internet connections generally, smart phones, public safety forces and operations, etc.

## Information Protection Based on Nanosecond Synchronization of Time Scales in Meteor Burst Channel

V. A. Korneev, V. V. Sidorov, and L. A. Epictetov. Kazan State University, Kazan, Russia. October 7, 2007. Automation and Remote Control, 2008, Vol. 69, No. 6, pp. 1065–1076. © Pleiades Publishing, Ltd., 2008

### INTRODUCTION

Secure encryption key dissemination required by modern methods of cryptography is one of the acute problems for today's technology. The main obstacle here is the lack of fully cryptographic means for long-distance key transfer. The importance of this problem lies in the fact that information protection is achieved by mathematical methods, based on pseudo-random sequences and random encryption keys. These methods are not proven to be unbreakable "in principle" and considering modern means of cryptanalysis aided by supercomputers, might fail given time, money or both. Guaranteed protection of information can be achieved only by frequent change of keys, what makes the key change procedure one of the most important technical problems. There are two ways of channel-based information protection currently in active development that can be used for key dissemination: quantum cryptography [1] and meteor cryptography [2, 3]. Quantum cryptography uses the uncertainty principle and currently is actively developed for application in fiberoptic channels. It is based on possibility to detect eavesdropping in such a channel. Meteor cryptography uses randomness of spatial parameters of the wave-reflecting trail together with mirroring conditions for the particular pair of communicants and good phase reciprocity of radio wave propagation. This method provides generation of "nature-supplied" encryption keys exclusively—even though radio waves are used—for two communicants located at distances up to 2000 km. Meteor cryptography claims to guarantee information protection against eavesdropping by remote cryptanalyst because in such a system the information containing the keys is [sic] not transmitted. The keys are generated in receiving antennas. . . .

. . . Meteor encryption key generation is based on nanosecond time scale synchronization and high meteor channel reciprocity [13] that makes possible two-way carrier phase time transfer measurements, with radio wave propagation parameters varying for different meteor trails in the range of 1  $\mu$ s. High time scale synchronization precision allows to perform measurements of random components of current wave propagation parameters varying from trail to trail and use them as elements of key in Vernam cypher, thus providing perfect encryption according to Shannon's theorem [14]. Key generation procedure may not be performed on meteor trails used for time transfer, as time scale shift measurement gives away information about current wave propagation time in the response signal. The important question is how to

distribute the rare and short intervals of channel existence to successfully and efficiently perform both high precision time transfer and generation of naturally random key sequence.

As described earlier, meteor cryptography requires that the transmitted signals contain only coordinates of the communicating points and their time scales. The keys are generated specifically for particular communicants by measuring the phases of signals transmitted in opposite directions and scattered by meteor trails with random spatial and temporal positions. These keys are visible only for communicants, they are used once and can not be predicted, bought or stolen. However this use of the meteor channel makes two working modes necessary: time transfer and key generation. In order to estimate the capacity of meteor key generation channel we first introduce a simpler problem of achieving the most of the possible key bits by measuring the full random wave propagation time with carrier frequency phase ambiguity resolved. The key generation channel capacity depends here only on the properties of meteor trails, synchronization precision and random portion of wave propagation time. The decision of switching from time-transfer mode into measurement of signal propagation time is made here by the threshold value of time-scale shift estimate error.

**Comment.** See following page for more articles on this meteor burst channel secure long-distance encryption that is more secure than mathematical methods. This, by itself, makes meteor burst signaling of critical importance, especially given its low cost. All modern telecom and other public and governmental electronic-information systems require highly secure encrypted systems. This is a core national security matter.



INTERNATIONAL CIVIL DEFENCE ORGANISATION

Protection of the population, property,  
and the environment

Communication technologies are now a very important part in Disaster Reduction and Prevention. The seminar included some presentations made by chinese technical experts in use of Communication Technologies in Disaster Prevention and Management.

\* \* \* \*

Disaster Reduction Applications of Wireless WAN based on  
Meteor Burst Communications – Beijing Starrycom Tech.

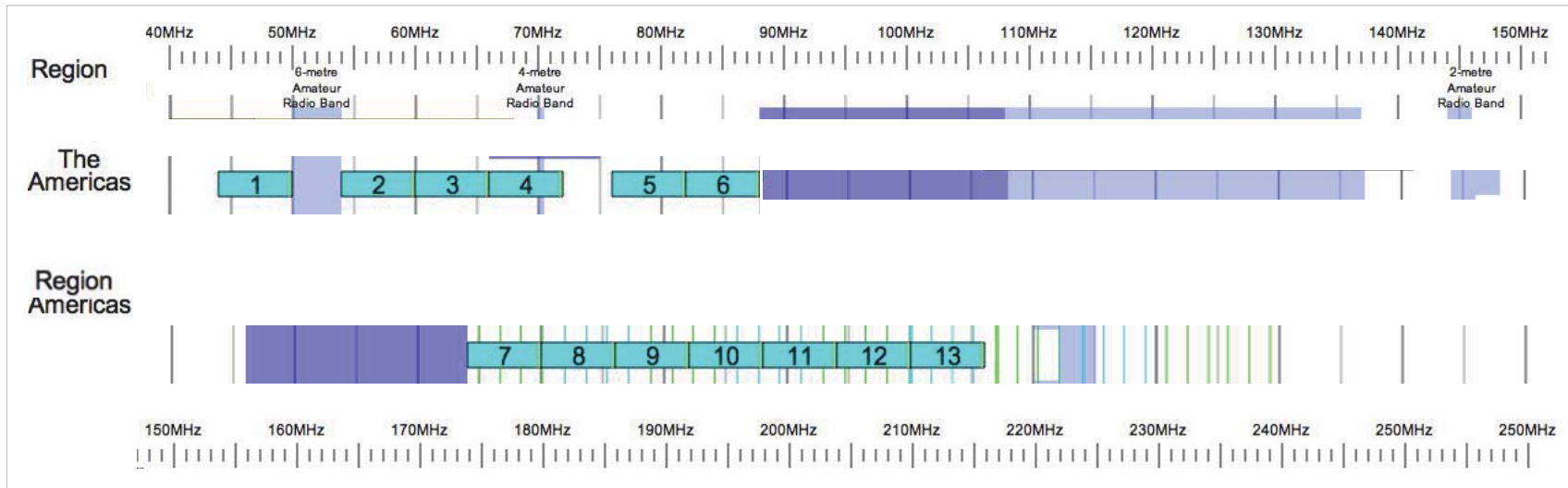
## I. Advanced Meteor Burst Radio Signaling (MBRS) – what and why

# 8

## Spectrum availability

(and no other spectrum users affected)

TV channel and frequencies in US. Below slides discuss use of some of these TV Channels' spectrum for MBRS, for some direct use, and some passive use.



Above charts from: [https://en.wikipedia.org/wiki/Television\\_channel\\_frequencies#/media/File:VHF\\_Usage.svg](https://en.wikipedia.org/wiki/Television_channel_frequencies#/media/File:VHF_Usage.svg)

**VHF low-band (band I)**  
(frequencies in MHz)

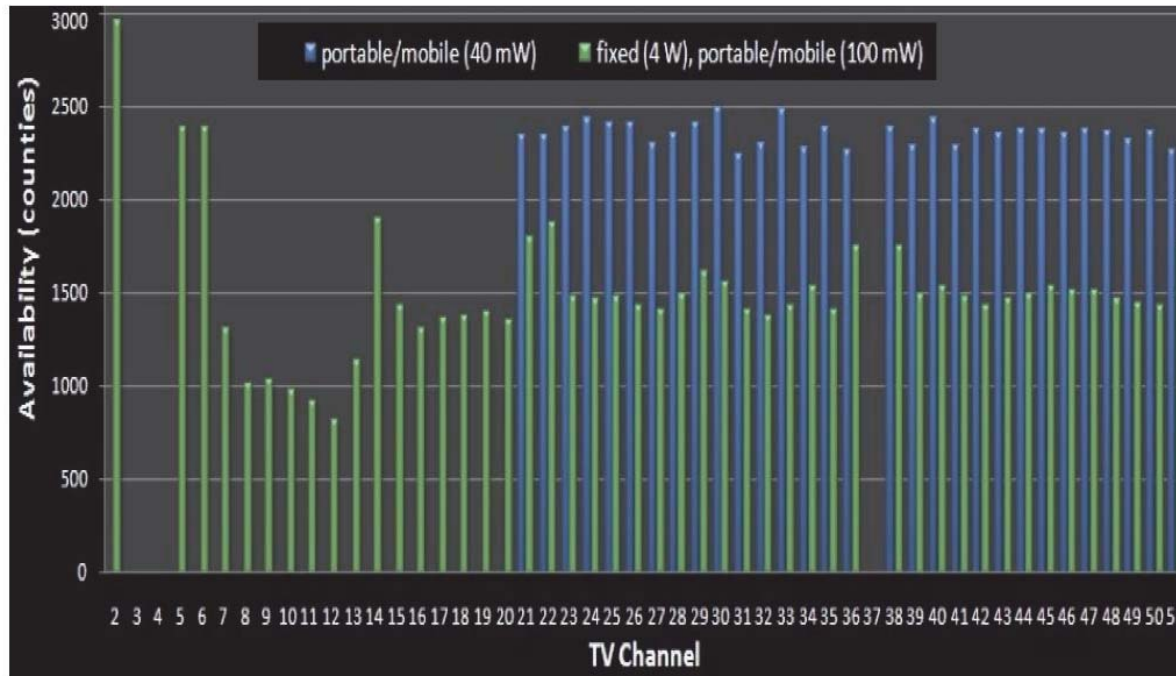
Channel	Lower edge	Video carrier	ATSC pilot	Audio carrier	Upper edge
2	54	55.25	54.31	59.75	60
3	60	61.25	60.31	65.75	66
4	66	67.25	66.31	71.75	72
(Break in band plan)					
5	76	77.25	76.31	81.75	82
6	82	83.25	82.31	87.75	88

**VHF high-band (band III)**  
(frequencies in MHz)

Channel	Lower edge	Video carrier	ATSC pilot	Audio carrier	Upper edge
7	174	175.25	174.31	179.75	180
8	180	181.25	180.31	185.75	186
9	186	187.25	186.31	191.75	192
10	192	193.25	192.31	197.75	198
11	198	199.25	198.31	203.75	204
12	204	205.25	204.31	209.75	210
13	210	211.25	210.31	215.75	216

Above tables from: [https://en.wikipedia.org/wiki/North\\_American\\_television\\_frequencies](https://en.wikipedia.org/wiki/North_American_television_frequencies)

Reference 14



From: *Wireless Sensor Networking over White Spaces*, by A. Saifullah, C. Lu at Washington University, and J. Liu, R. Chandra, S. Sankar at Microsoft Research.

Potentially, MBRS for or in partnership with federal agencies may be able to [directly use Channels 3 and 4 spectrum also](#), under rule waivers for good cause that I believe can easily be shown, along lines of the notes in the page above.

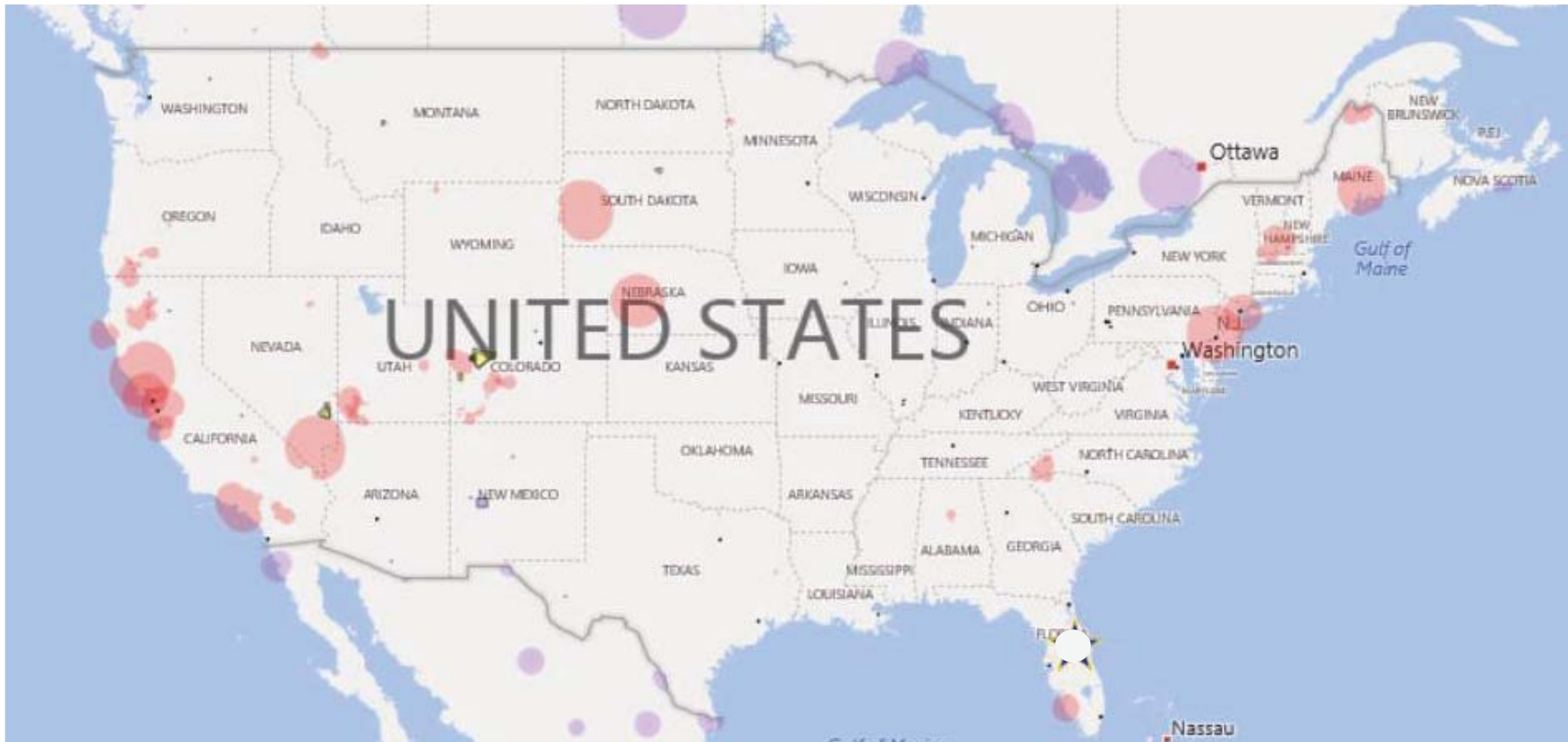
Figure 1: White space channel availability in US

## 2.1 Availability

Compared to IEEE 802.15.4 or Wi-Fi, white spaces offer a large number channels. For example, the spectrum between 512MHz and 698MHz has 30 channels (each TV channel is 6 MHz wide). The availability of white spaces depends on location. Rural (and suburban) areas, typically have more white spaces than urban areas due to lesser number of TV stations. Figure 1 shows county based availability of white space spectrum per channel from channel 2 to 51 (except 37 that is not

allowed for usage) in USA, based on the statistics collected by Spectrum Bridge [9]. For a channel in x-axis, the corresponding value on y-axis indicates the number of counties among 3142 counties nationwide where the channel is available as white space. Many wireless sensor network deployments such as those for habitat monitoring [25], environmental monitoring [20], and volcano monitoring [26] are in rural areas, making them perfect users of white spaces.

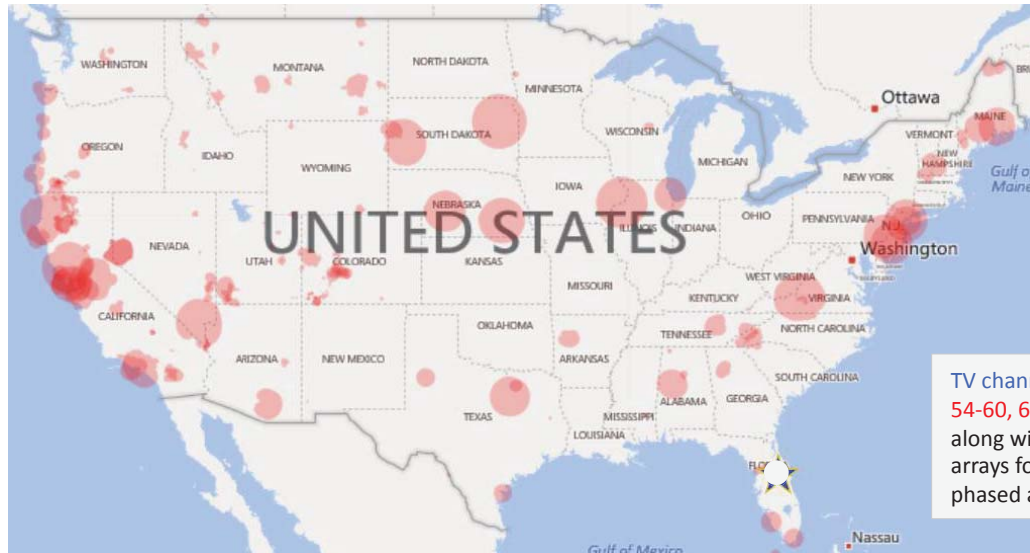
This TV Channel 2 spectrum, 54-60 MHz, can be used for MBRS [directly](#). It can [also](#), with Channels, 3, 4, 5, and 6 (see next page) be used as a component in MBRS passive multistatic [radar](#).



TV channel 2, from: 54-60 MHz. These signals can be received along with Part 22 low VHF VHF ~40 MHz signals in phased arrays for MBRS, including for ipPNT, pPNT, and other applications, especially in the phased arrays. See slides above. This spectrum may be used for “TV White Space” (“TVWS”) fixed radios communicating with other fixed radios. FCC rule 47 CFR §15.707(b). This this regard: (1) The MBRS base stations are *best* located, due to MBRS’s intrinsic nature, *far away* from the urban areas, and few other areas of these TV Channel 2 stations. (2) MBRS remote *fixed* receivers can easily comply with TVWS rules, and will often be in remote areas. (3) The vast majority of the MBRS *mobile* remote receivers, and the most critical mobile applications, will be on broadcast basis, receiver only in the remote device, and there are no limitations in TVWS rules for receive-only devices. (4) MBRS use of this spectrum, in this manner, will be supplemental to dedicated exclusive spectrum as proposed herein (some federal, and some other) and any interference to the MBRS remote radios will only decrease the data rate, not the reliability or data rate for critical functions. (5) MBRS as described herein will have probably unmatched intrinsic and engineered-in means to minimize interference from any sources, and thus this “extra” data rate or capacity will be close to fully available. Thus, use of 54-60 MHz for MBRS under TVWS rules will be highly compatible with the purpose of TVWS rulemaking (to increase intelligent use of the spectrum nationwide, in non-interfering manner, including for new advanced applications, etc.), as well as fully compliant with the rules.

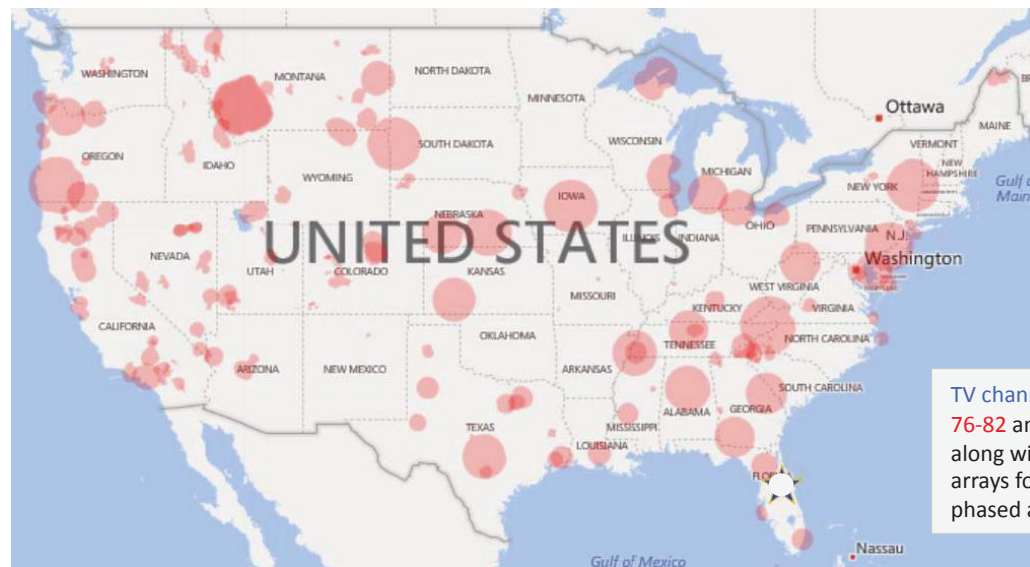
Above maps generated here: <http://whitespaces.spectrumbridge.com/WhiteSpaceSearch/interactive-map.aspx> (The star was embedded there by spectrum bridge not us.)

## Reference 15



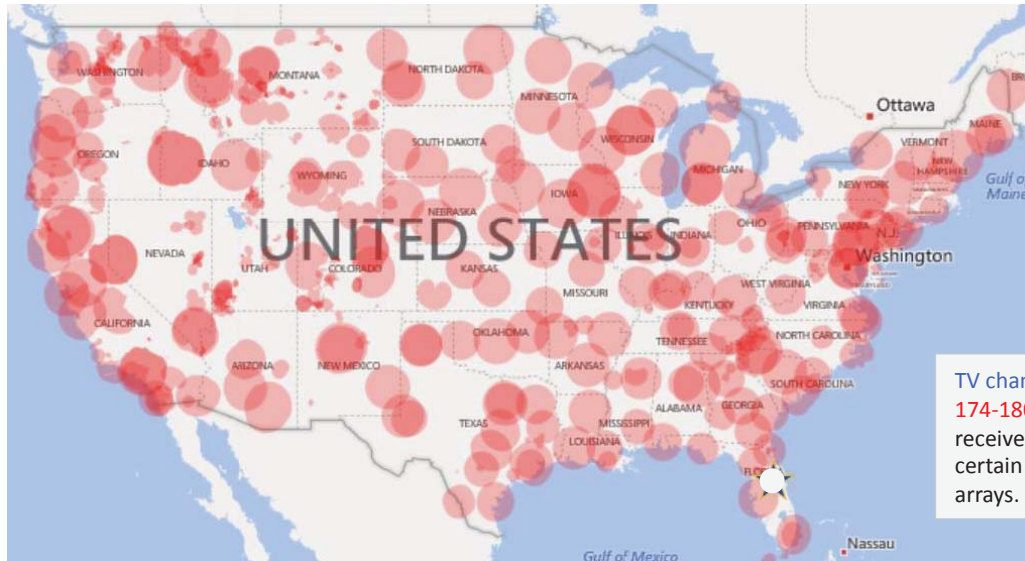
Maps of some VHF TV channels to show locations in US for purposes noted below.

TV channel 2, 3, and 4 high power stations, from: 54-60, 60-66, and 66-72 MHz. These signals can be received along with Part 22 low VHF ~40 MHz signals in phased arrays for certain pPNT and other applications, especially in the phased arrays. See slides above.



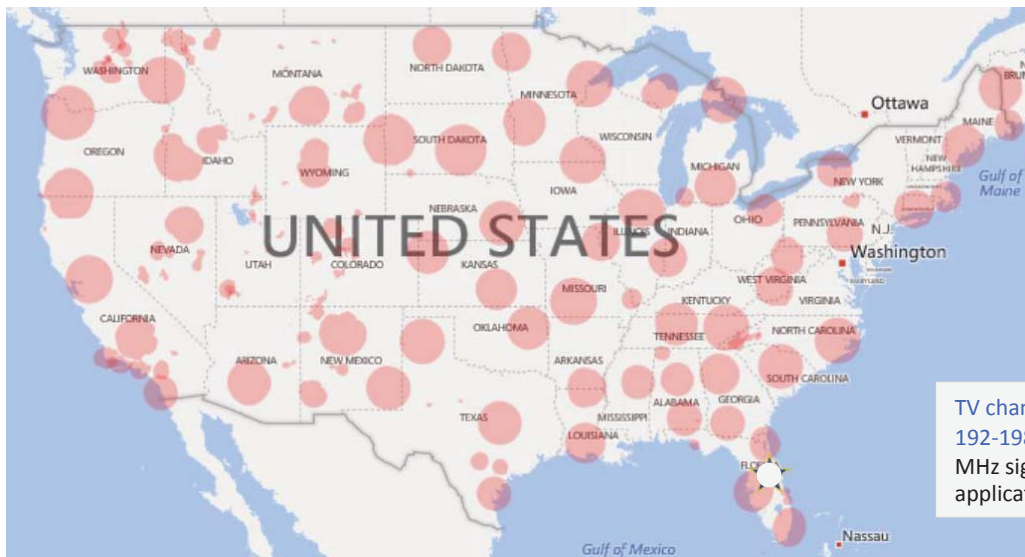
TV channel 5 and 6 high power stations, from 76-82 and 82-88 MHz. These signals can be received along with Part 22 low VHF ~40 MHz range signals in phased arrays for certain pPNT and other applications, especially in the phased arrays. See slides above.

Above maps generated here: <http://whitespaces.spectrumbridge.com/WhiteSpaceSearch/interactive-map.aspx> (The star was embedded there by spectrum bridge not us.)



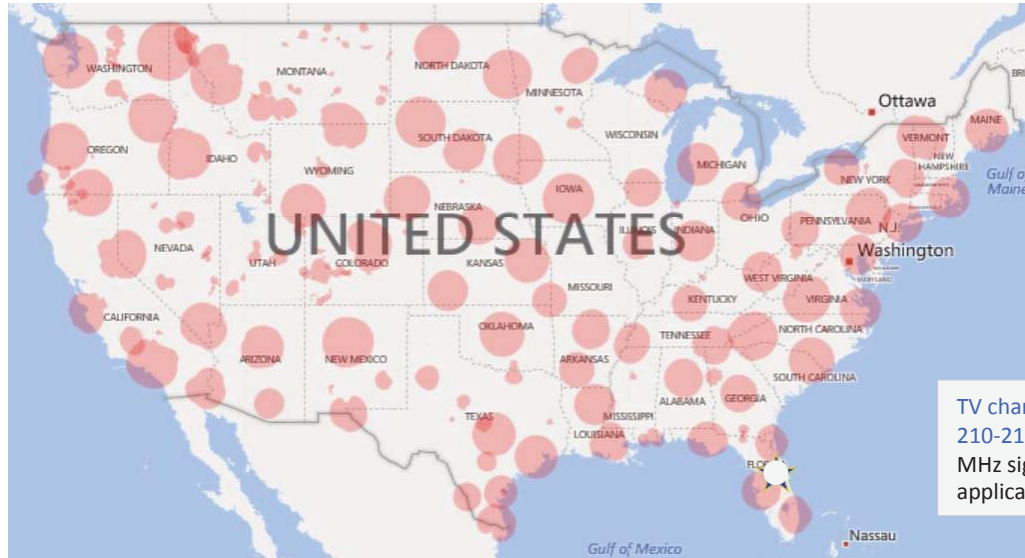
Continued. Maps of some VHF TV channels to show locations in US for purposes noted below.

TV channel 7, 8, and 9 high power stations, from: 174-180, , 180-186, and 192-198 MHz. These signals can be received along with ~200 MHz signals in phased arrays for certain pPNT and other applications, especially in the phased arrays. See slides above.



TV channel 10 high power stations, from: 192-198 MHz. These signals can be received along with ~200 MHz signals in phased arrays for certain pPNT and other applications, especially in the phased arrays. See slides above.

Above maps generated here: <http://whitespaces.spectrumbridge.com/WhiteSpaceSearch/interactive-map.aspx> (The star was embedded there by spectrum bridge not us.)



Continued. Maps of some VHF TV channels to show locations in US for purposes noted below.

TV channel 13 high power stations, from: 210-216 MHz. These signals can be received along with ~200 MHz signals in phased arrays for certain pPNT and other applications, especially in the phased arrays. See slides above.

#### Comments.

These **TV VHF channel** signals--described and in part mapped in this and preceding pages-- can best be put to use as “signals of opportunity” (SsOp) for pPNT and associated critical wireless applications *by the means noted herein*, mostly above. This involves:

- (1) Use of modern advanced, cost-effective, modular, SDR **phased arrays** to transmit and receive for GNSS-independent **pPNT**;
- (2) These phased arrays, as shown above, that operate from about **10 to 270 MHz** (they are made to do that already); and
- (3) Using the **TV VHF** SsOp to enhance the pPNT based on skywave Meteor Burst (MB) signaling **along with** our dedicated spectrum in the **~40 MHz range** (Part 22), but also terrestrial (and some skywave) signaling in our **~200 MHz**, **200 MHz**, and **mLMS** and other **900 MHz**.
- (4) This **cost-effective robust pPNT** with dedicated-spectrum transmit and receive, and TV-channel transmissions for enhancements, will support terrestrial and airborne (including Drones) mobile-device pPNT – **precise Position, Navigation and Timing**-- that is **essential to ubiquitous smart transport, energy, environment, public safety, defense, etc.**

Above maps generated here: <http://whitespaces.spectrumbridge.com/WhiteSpaceSearch/interactive-map.aspx> (The star was embedded there by spectrum bridge not us.)

Note: From NTIA Assessment document.

Copy at: <http://www.ntia.doc.gov/files/ntia/publications/section3a.pdf>

This section provides a detailed assessment of the reallocation options for the bands under consideration. Factors such as, the Federal and non-Federal use of the band, estimated mission impact and cost to the Federal agencies, and potential benefits to the public will be addressed. A band-by-band assessment of these factors is presented and recommendations are made as to which bands will be included in the spectrum reallocation plan.

## **32-33, 34-35, 36-37, 38-39, AND 40-42 MHz BANDS**

### **Reallocation Considerations and Impact**

The bands between 32-42 MHz are part of what is referred to as the lower Very High Frequency (VHF) spectrum. These bands are used by the Federal Government primarily for providing tactical and non-tactical communication. Because of the unique propagation characteristics in this region of the spectrum, wide area coverage is possible with a minimum number of transmitters. One type of communication that can only be supported in the lower VHF spectrum is meteor burst communications.<sup>3</sup> It has been determined that the 40-42 MHz band is the optimum band for meteor burst systems because there is a somewhat larger meteor scatter signal return and greater channel throughput.<sup>4</sup>

Re Dept. of Commerce [NIST](#) station [WWV](#), at [20](#) and [25 MHz](#), as a MBRS pPNT potential signal of opportunity [1]  
(not required, but may be useful)

See: <http://www.nist.gov/pml/div688/grp40/www.cfm>

[WWV](#) has resumed broadcasting on [25 MHz](#) [1] on an [experimental](#) basis. The broadcast consists of the normal [WWV](#) signal heard on all other [WWV](#) frequencies, at the same level of accuracy.

\*\*\*\*

Current [25 MHz](#) Broadcast Specifications:

Schedule: typically continuous. As an experimental broadcast, the 25 MHz signal may be interrupted or suspended without notice. Radiated Power: [2.5 kW](#)

\*\*\*\*

[NIST](#) radio station [WWV](#) broadcasts time and frequency information 24 hours per day, 7 days per week to millions of listeners worldwide. [WWV is located in Fort](#)



[Collins, Colorado](#), about 100 kilometers north of Denver. The broadcast information includes time..., standard time intervals, standard frequencies, UT1 time corrections, a BCD time code, geophysical alerts and marine storm warnings.

\*\*\*\*

[WWV](#) operates in the high frequency (HF) portion of the radio spectrum....radiates 10,000 W on 5, 10, and 15 MHz; and [2500 W](#) on 2.5 and [20 MHz](#). [1]

See: [https://en.wikipedia.org/wiki/WWV\\_\(radio\\_station\)](https://en.wikipedia.org/wiki/WWV_(radio_station)) [footnote added]

[WWV's 20 MHz](#) signal [1] was used for a unique purpose in 1958: to track the disintegration of Russian satellite Sputnik I after the craft's onboard electronics failed. Dr. John D. Kraus, a professor at Ohio State University, knew that a [meteor](#) entering the upper atmosphere leaves in its wake a small amount of ionized air. This air reflects a stray radio signal back to Earth, strengthening the signal at the surface for a few seconds. This effect is known as [meteor scatter](#). [2]

See: <http://radiojove.gsfc.nasa.gov/library/newsletters/latest/#6>



Thomas Ashcraft reports that on [November 19th, 2015](#) he picked up [meteor scatter](#)... reflections of transmissions from [WWV](#) at [25 MHz](#) and [20 MHz](#), within range of Radio Jove equipment. Though he was not using the standard Radio Jove set this event opens up exciting possibilities for Radio Jove observers. Any one else want to try to catch a meteor trail?

-----  
[1] Both 25 MHz and (with more noise mitigation issues) 20 MHz result in MB propagation as noted above.

[2] "Meteor scatter" is another term for "meteor burst" radio propagation.

Re: DOC NIST's [WWVB](#) at 60 kHz as a MBRS pPNT timing signal, in addition to MB timing

(Same applies to WWB's various HF frequency broadcasts)

See: <http://www.wired.com/2013/07/wwvb-time-radio/>  
"The Most Important Radio Station You've Never Heard of Marks 50 Years on the Air"

Use of WWV and WWVB for the distribution of standard time (and frequency), with other methods including MBRS is discussed in various papers, sometimes in the same paper, e.g.: <http://tf.boulder.nist.gov/general/pdf/1743.pdf>

WWVB provides coverage of the continental US. See maps here:  
<http://www.ntp-time-server.com/wwvb/wwvb.html>

Casio Edifice watch with WWVB signal for timing:  
[http://www.casio-intl.com/asia-mea/en/wat/edifice/tough\\_movement/](http://www.casio-intl.com/asia-mea/en/wat/edifice/tough_movement/)

This shows very low signals, for essential data, with robust modulation, can be received even in very small portable devices with body and ground radio-signal 'clutter.' The same applies to MBRS signals at much higher range.

For additional comparison, for eLORAN at 90-110 kHz, with 30-120 dBμV/m usable signal levels, a professional grade receiver has antenna size 19 x 19 x 8 cm: see: [http://www.reelektronika.nl/images/stories/reelektronika\\_LORADD\\_SP\\_Specs.pdf](http://www.reelektronika.nl/images/stories/reelektronika_LORADD_SP_Specs.pdf)

Also see next-generation, [cell-phone size](#), new Loran antennas described in this paper: [http://waas.stanford.edu/papers/DeLorenzo\\_ILA\\_2009.pdf](http://waas.stanford.edu/papers/DeLorenzo_ILA_2009.pdf)  
See next page.



#### ■ North America Signal (WWVB)

The U.S. calibration signal (60kHz) is transmitted from Fort Collins, Colorado. It is maintained by the National Institute of Standards and Technology.



## Distribution of Standard Frequency and Time Signals

A. H. Morgan, with the National Bureau of Standards, Boulder, CO. 1967

Abstract - This paper reviews the present methods of distributing standard frequency and time signals (SFTS)....

.... A technique employed by NBS to improve the transmitted accuracy of the frequencies of [WWV](#) and [WWVH](#) was to use the received signals of WWVB (60 kHz) and WWVL (20 kHz) at these stations to remotely control them. The NBS atomic standards are located at Boulder, Colo., and the transmissions of WWVL and WWVB, which stations are located about 50 miles away, are remotely phase controlled by means of a VHF phase-lock system....

### VII. PROMISING TECHNIQUES FOR FUTURE STUDY

There are several techniques for distributing SFTS which appear to be promising and should receive further study. They involve use of: 1) satellites, 2) [meteor trial reflections](#) of VHF radio signals (also called "[meteor burst](#)"),...

## A Miniaturized Loran H-field Antenna for Handheld Devices

David S. De Lorenzo, Sherman C. Lo, Morris Cohen, Jeff Chang,  
Umran S. Inan, Per K. Enge (Stanford University)

Table 1. Loran H-field Antenna Evolution.

Parameter	Gen-1	Gen-2	Gen-3	Gen-4 (tbd)
Antenna size	50cm	10cm	5cm	2.5cm
Wire gage	22 AWG	26 AWG	26 AWG	26 AWG
# of turns	9	19	37	74
Inductance	0.16 mH	0.10 mH	0.13 mH	0.23 mH
Resistance	1 $\Omega$			

The H-field antennas were integrated with the LNA module and line receiver support electronics as indicated in Figure 3. The grey aluminum box contains the preamplifier and filtering circuits; the red case is the line receiver [Cohen *et al.*, 2010].

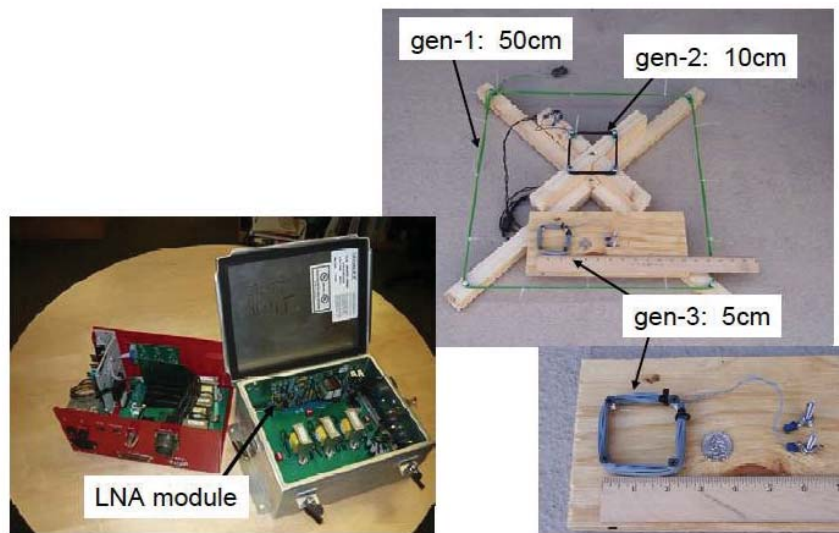


Figure 3. ELF/VLF radio reception system with various small-form-factor Loran antennas.

Continued from preceding, and continued on next page.

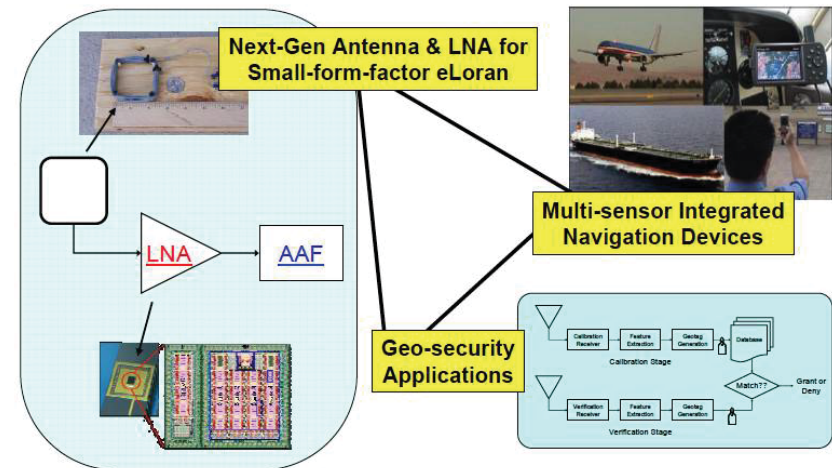


Figure 1. Enabling a Small Loran Antenna for Integrated Navigation Devices.

MBRC receive-only antennas, such as to receive broadcast-mode nRTK corrections, and ipPNT signals (GPS-independent precise Position, Navigation and Timing) can be as small, but **should perform better this small**, including since (1) the signals are in the ~40 MHz range, far shorter than Loran at 100 kHz; and can use (2) OAM to reduce signal to noise, (3) Optical detection of radio waves through nano-mechanical transducers (to greatly reduce internal noise), (4) base- and remote-phased arrays available in the MBRS range, and other methods (see section \_\_ on noise reduction and use).

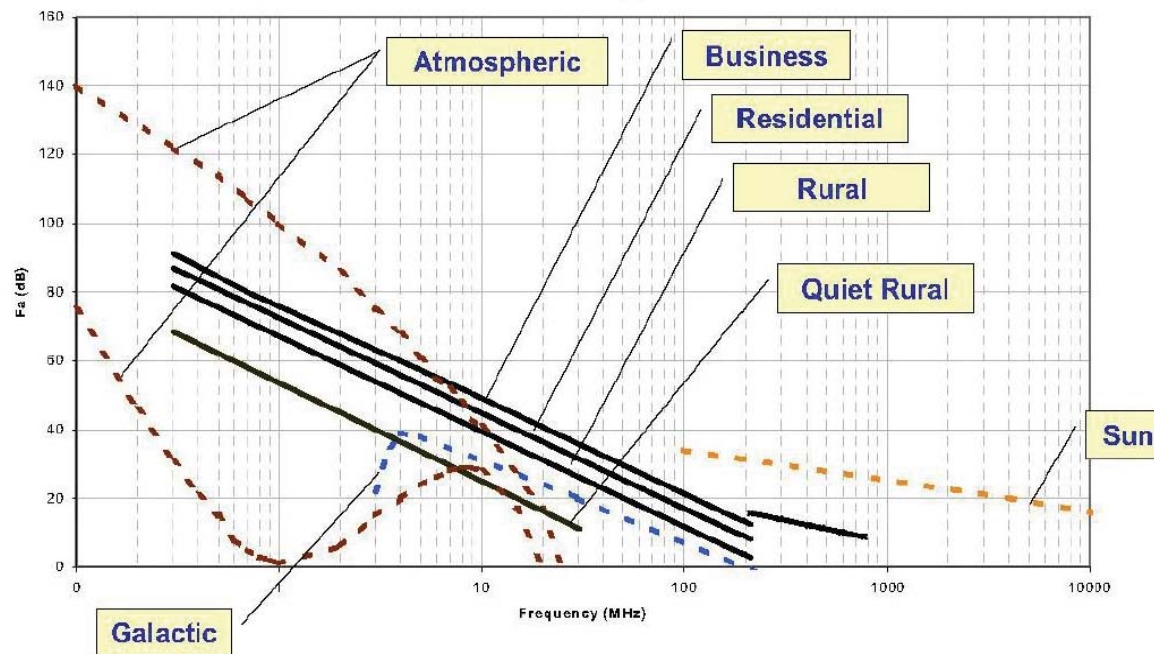
The below explains the noise and 'skip' problems.

As indicated on the next page, these can largely solved by the described advanced MBRC in this spectrum range.

The lower VHF band was studied by the PSWAC as a possible candidate to satisfy future public safety spectrum requirements.<sup>12</sup> It was determined by the PSWAC that the spectrum from 30 to 50 MHz is good for wide area coverage from mobiles to dispatch centers in open terrain. However, it was determined that portable radios operate poorly due to antenna limitations. Frequencies in this part of the radio spectrum were also found to be subject to "skip" interference between widely separated systems. The bands between 30-50 MHz are in a region of the radio spectrum where the ambient noise levels are high, particularly on highways and near industrial areas. The increased noise levels can limit the performance of a communications system by restricting the operating range, generating errors in messages and data, and in extreme cases preventing the successful operation of a receiver. Moreover, the availability of equipment in the lower VHF band is questionable. Both Ericsson and Motorola have indicated that they will no longer manufacture equipment capable of operating in the 30-50 MHz frequency range.<sup>13</sup> The PSWAC concluded that these technical constraints impair future use of the band to satisfy public safety spectrum requirements.<sup>14</sup>

Note: From NTIA Assessment document. Copy at: <http://www.ntia.doc.gov/files/ntia/publications/section3a.pdf>

# VHF Noise Backgrounds



**Figure 2 Noise distribution with Frequency**

The levels in Figure 2 are taken from the ITU-R recommendation [P.372], which contains descriptions of the various types of electromagnetic noise.



Note: The above is from: "Spectral Occupancy at VHF: Implications for Cognitive Radios." Fall 2005 IEEE Vehicular Technology Conference (Dallas). By Steve Ellingson of VT, MPRG.

Most of this noise in and around ~40 MHz, for MBRS, can be eliminated by technologies presented herein including:

- (1) Modern base-station phased arrays
- (2) Remote-device "arrays" (multi coherent sdr, and antenna synch)
- (3) Coded continuous wave meteor radar (see slide above)
- (4) OAM and other means to improve corrections of polarization and vorticity distortion in signals from Ionosphere
- (5) Advances in "cognitive" radio.
- (6) Optical detection of radio waves through nano-mechanical transducers
- (7) Ongoing advances in computer tech applied to the above and radio/ antenna tech generally

The same tech will greatly decrease RF signal levels and improve data throughput.

## Spectral Occupancy at VHF: Implications for Frequency-Agile Cognitive Radios

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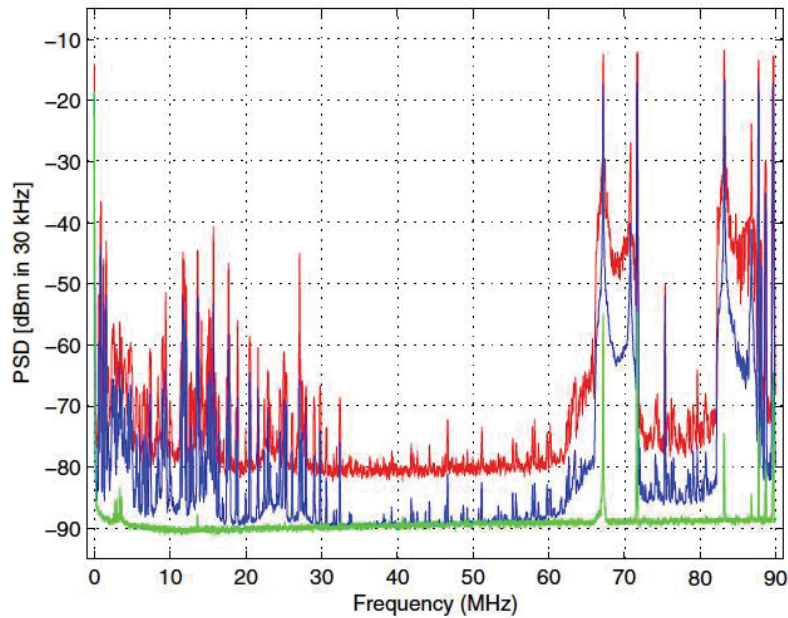


Fig. 1. Urban setting, 0–90 MHz. *Red/Top*: Max; *Blue/Middle*: Mean; *Green/Bottom*: Mean, matched load replacing antenna. (Note limited isolation in the matched load case; see text.) Resolution: 30 kHz.

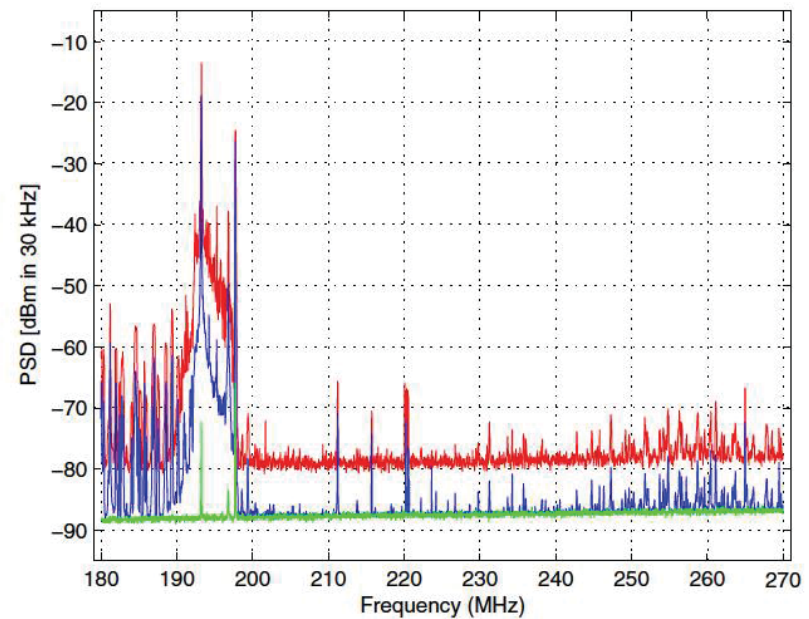


Fig. 3. Urban setting, 180–270 MHz. *Red/Top*: Max; *Blue/Middle*: Mean; *Green/Bottom*: Mean, matched load replacing antenna. Resolution: 30 kHz.

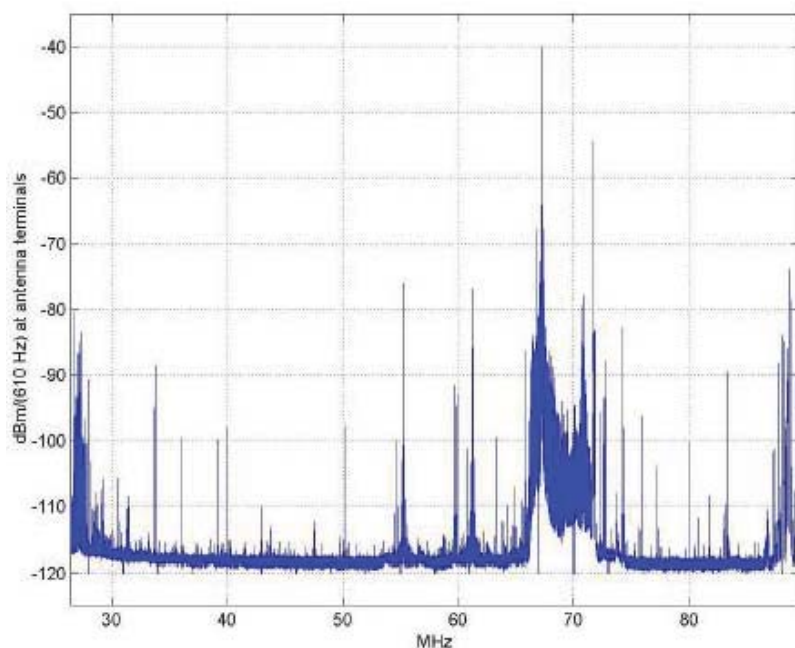


Fig. 8. Rural setting, 25–90 MHz. Mean PSD. Resolution: 610 Hz.

#### IV. IMPLICATIONS FOR COGNITIVE RADIO

It is noted that the spectral occupancy is indeed sparse in the measurements reported here. There is very little evidence of persistent activity above  $-87$  dBm per 30 kHz in the urban setting, or above  $-110$  dBm per 610 Hz ( $-93$  dBm per 30 kHz) in the rural setting. In the urban setting, 30–60 MHz and 140–180 MHz were observed to be possible candidates for frequency-agile operation. In these bands, 40 and 67 openings (respectively) were found with bandwidths ranging from less than 30 kHz to greater than 3 MHz. However, it is

This paper indicates availability of large amounts of spectrum, on basis of its use in time, in both urban and rural areas. So do other spectrum use and occupancy field studies and reports from federal agencies.

Currently I cannot comment herein on some FCC licensees and licenses in this range, as indicated above.

Again, MBRS uses  $\sim 40$  MHz as defined above (25–55 MHz).